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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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Steam Road Rollers & Tractors.

A. G. Mumford, Ltd., CULVER STREET WORKS, COLCHESTER.
ON ADMIRALTY AND WAR OFFICE LISTS.
ENGINES for Torpedo Boats, Yachts, Launches.
BOILER FEED PUMPS.
See advertisement pages 24 and 25.
PATENT WATER-TUBE BOILERS.
AUTOMATIC FEED REGULATORS.
And Auxiliary Machinery as supplied to the Admiralty. 2179

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FLOATING CRANES. COAL BUNKERING VESSELS.
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See half-page Advert, last week and next week. 1382

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GEORGE RUSSELL & CO., LTD., Motherwell, near Glasgow. 1137

STEEL TANKS, PIPES, GASHOLDERS, &c.
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See Advertisement last week, page 88.

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See Page 80.
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Specification and Workmanship equal to Main Line Locomotives.
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Cochran MULTITUBULAR AND CROSS-TUBE TYPES. Boilers.
See page 17. 1134

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See Advertisement, page 75, May 11.

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SHALLOW DRAFT VESSELS. 818

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For Boilers of all types.
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Naval Outfits a Speciality, also for Merchant Ships, for Factories, Locomotives, and Industrial Process Furnaces of all kinds.
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Telephone No.: Central 2632.
Telegrams: "Warmth." 4078

Locomotives Tank Engines designed and constructed by MANNING, WARDLE AND COMPANY, LIMITED, Boyne Engine Works, Leeds. Od. 3487
See their Illus. Advertisement, page 93, last week.
RAILWAY AND TRAMWAY ROLLING STOCK.

Hurst, Nelson & Co., Ltd. THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 3382

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MAKERS of WHEELS and AXLES of all kinds.
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Undertake SPECIAL MACHINE WORK of any description.
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LATHE WORK up to 10 ft. diameter.
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Chief Offices: 129, Trongate, Glasgow. Od 8547
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Powering of Vessels.—A Practical Course of Instruction by Correspondence.—Address, for particulars and terms, 1049, Offices of ENGINEERING.

John Bellamy, Limited, MILLWALL, LONDON, E. 1316
GENERAL CONSTRUCTIONAL ENGINEERS,
Boilers, Tanks, & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETED STEAM AND VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

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Tubes AND Fittings AND Steel Plates.
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GLASGOW - BIRMINGHAM - LONDON.
See Advertisement Page 63. 1111

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STEAM ENGINES AND TURBINES.
GAS AND OIL ENGINES.
AIR COMPRESSORS.
REFRIGERATING PLANT.
See Advertisement, page 55, May 11.

Gearing for Power Transmission.
Including Machine Moulded GEAR WHEELS up to 10 feet dia.;
FLY WHEELS (rope or spur drive) up to 28 feet dia.;
IRON CASTINGS up to 15 tons each, in Loam, Dry or Green Sand;
ENGINES: "Uniflow," "Corliss" or Drop Valve.
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The Strongest Chain in the World.
Sole Manufacturers: WELDLESS CHAINS, LTD., 50, Wellington Street, GLASGOW. 606

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Telephone: Central 7424. Od 555

Phone—Holb. 541. Tele.—Andrubo, Holb., London.
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MACHINE-CUT
D.B.S. GEARS of every description. 1440

DAVID BROWN & SONS (Hudd.) LTD., Lockwood - - - - - Huddersfield.

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CARELS DIESEL & STEAM ENGINES (LONDON), LTD., Carlton House, Regent Street, London, S.W. 1. Telephone: Regent 3484.

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FRED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, } ROW'S PATENTS.
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
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LAND AND MARINE
YARROW BOILERS. 819

Matthew Paul & Co., Ltd., LEVENFORD WORKS, Dumbarton. 763
See Full Page Advt., page 40, April 27.

Forgings.
Walter Somers, Limited, HALESOWEN. 7116

Taylor & Challen Presses
For Production of SHEET METAL WORK, COINAGE, CARTRIDGES AND GUNPOWDER.
Foundry, Works, and Showrooms: BIRMINGHAM.
See half page advert., page 58, April 27. 8195

Head, Wrightson & Co., LIMITED.
See Advertisement page 60. 2403

Railway Switches and Crossings.
T. SUMMERSON & SONS, LIMITED, DARLINGTON. 1313

THE GLASGOW ROLLING STOCK AND PLANT WORKS.
Hurst, Nelson & Co., Ltd., Builders of RAILWAY CARRIAGES, WAGONS ELECTRIC CARS, and EVERY OTHER DESCRIPTION OF RAILWAY and TRAMWAY ROLLING STOCK.
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Transporters.
Lifts.
S. H. HEYWOOD & Co., LTD., Reddish. 1357

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Pott, Cassels & Williamson, MOTHERWELL, SCOTLAND. 939
See half-page Advertisement, page 66, May 11.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by Sir WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 1311

ARTHUR LEONARD PAILTHORPE deceased.

Pursuant to the Law of Property Amendment Act, 1859.

Notice is Hereby Given that

all creditors and other persons having any claims or demands against the estate of Arthur Leonard Pailthorpe late of "Little Hatch" Pennsylvania Road, Sanderstead, Surrey, and Hampton Works, Hampton Road, Croydon, Surrey, Engineer deceased (who died on the 26th day of May 1922 and whose Will was proved in the Principal Probate Registry on the 7th day of September 1922 by Mary Geraldine Pailthorpe, Alan Herbert Pailthorpe and Frederick Gerald Pailthorpe the Executrix and Executors therein named) are hereby required to send particulars in writing of their claims and demands to the undersigned, the solicitors for the said Executrix and Executors on or before the 30th day of June 1923, after which date the said Executrix and Executors will proceed to distribute the assets of the said deceased amongst the persons entitled thereto, having regard only to the claims and demands of which they shall then have notice; and they will not be liable for the assets of the said deceased or any part thereof, so distributed, to any person or persons of whose claims or demands they shall not then have had notice.
Dated this 12th day of May 1923.
CARTWRIGHT & CUNNINGHAM,
47, Paternoster Row, London, E.C.4.
Solicitors for the said Executrix and Executors.
A 529

University of Edinburgh.

APPOINTMENTS COMMITTEE.

The Committee keeps a Register of Members of the University desiring to obtain educational, technical, commercial or other posts, and employers of all kinds are invited to make use of the Register in regard to vacancies. On notification of vacancies the Committee is willing either to furnish suitable candidates with the particulars, or, if desired, to recommend selected candidates for consideration. In every case the Committee will obtain, so far as possible, the testimony of Professors and Lecturers to whom candidates may be personally known.
There is no commitment of any kind in making use of the Register, and no fee or commission is charged.
Further particulars regarding the facilities offered by the Committee may be obtained from the Secretary, MR. T. A. JOYNT, The Old College, Edinburgh, to whom all communications should be addressed. A 519

Correspondence Courses for

Inst. Civil Engrs., Inst. Mech. E., London Univ. (Matric., Inter., B.Sc.), and ALL ENGINEERING EXAMINATIONS personally conducted by Mr TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., &c. Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to 8/11, TRAFFORD CHAMBERS, 58, SOUTH JOHN STREET, LIVERPOOL. 1296

Engineering Salesmanship

and SALES MANAGEMENT.—Write for brochure describing our special Course of training for posts of unlimited scope in this lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 333, Oxford Road, Manchester. 1401

TENDERS.

URBAN DISTRICT COUNCIL OF ENFIELD.

The Council are Desirous

of PURCHASING SECOND-HAND MACHINERY as follows:—
TWO Double inlet, Double standard Belt-driven Centrifugal Pumps, either 4 in., 5 in. or 6 in. bore.
ONE Vertical Cross Tube Boiler of about 6 HP. 80 lbs. pressure, complete with all fittings and mountings.
The above to be delivered to the Council's Sewage Farm, Cuckoo Hall Lane, Lower Edmonton, N.
Tenders, including a copy of last inspection certificate for the boiler, to be delivered to the undersigned not later than Twelve noon on Monday, 21st May, 1923.
By Order,
T. W. SCOTT,
Clerk to the Council.
Public Offices,
Enfield, Middx.
9th May, 1923. A 522

CITY OF CARDIFF EDUCATION COMMITTEE.

THE TECHNICAL COLLEGE.
Principal: CHARLES COLES, B.Sc. (Lond.).

The Services of an Assistant

INSTRUCTOR with good qualifications in Naval Architecture, Experimental Science and Mathematics are REQUIRED in the Marine Technical Department, which includes Marine Engineering and Navigation (B. o. T. Examinations). Practical Shipyard experience is desirable.
Commencing salary £300 per annum, subject to the Regulations of the Committee re percentage deduction.
Applications on foolscap paper, stating age, full qualifications, teaching and other experience, and giving copies of not more than three recent testimonials, should reach the Principal (from whom further particulars may be obtained) not later than May 30th.
The selected candidate, before being appointed, will be required to submit himself for examination by the Authority's Medical Examiner at Cardiff.
JOHN J. JACKSON,
Director of Education, City Hall, Cardiff.
15th May, 1923. A 554

PORT OF BRISTOL.

RECONSTRUCTION OF TRANSIT SHED "U," BRISTOL.

The Docks Committee invite

Tenders for the Reconstruction

(mainly in ferro-concrete) of the DOUBLE FLOOR TRANSIT SHED known as Shed "U," situate on Canon's Road, Bristol.
On and after Monday, the 28th day of May, 1923, a copy of the Form of Tender, General Conditions, Specification, Schedule of Prices, and a Copy of the Contract Drawings can be obtained from the undersigned on production of a receipt showing that a deposit of £5 has been paid to the General Manager and Secretary of the Docks Committee, to whom all cheques must be made payable. The deposit of £5 will be returned hereafter to all *bona fide* Tenderers.
Tenders must be enclosed in a sealed envelope, endorsed "Tender for Reconstruction of Shed 'U,' Bristol," and addressed to the General Manager and Secretary of the Docks Committee, 19, Queen Square, Bristol, and must be delivered to him, accompanied by all the prescribed documents and drawings, before Ten a.m. on Monday, the 18th day of June, 1923.
The Docks Committee do not bind themselves to accept the lowest or any Tender.
THOMAS A. PEACE,
Engineer,
Port of Bristol.
Chief Engineer's Office,
Avonmouth Docks,
18th May, 1923. A 561

DEPARTMENT OF PUBLIC WORKS,
Sydney, 31st January, 1923.
SYDNEY HARBOUR BRIDGE TENDERS—EXTENSION OF TIME.

Tenders are Invited by

the Government of New South Wales for the CONSTRUCTION OF THE SUPERSTRUCTURE AND SUBSTRUCTURE OF A CANTILEVER BRIDGE ACROSS SYDNEY HARBOUR FROM DAWES POINT TO MILSON'S POINT, embracing a main span of 1600 feet in the clear, centre to centre of main piers, and a length of main bridge 2600 feet centre to centre of anchor piers. The total length of main bridge and approach spans included in tender is 3810 feet; also an ALTERNATIVE TENDER for the CONSTRUCTION OF THE SUPERSTRUCTURE AND SUBSTRUCTURE OF AN ARCH BRIDGE ACROSS SYDNEY HARBOUR FROM DAWES POINT TO MILSON'S POINT, embracing a main span of 1650 feet in the clear centre to centre of bearings. The total length of main bridge and approach spans included in tender is 3770 feet. Either bridge is to provide for four lines of railway, six lines of vehicular traffic, and footway accommodation.
Copies of Specification, including Plans, Technical Information, General Conditions, and Tender Forms, may be obtained by *bona fide* tenderers on application to the Under Secretary for Public Works, Sydney, or to the Agent-General for New South Wales, Australia House, The Strand, London; the Minister of Railways and Canals, Ottawa; The Australian Trade Commissioner in the United States, New York; or the Bureau of Foreign and Domestic Commerce, Washington, D.C., United States.
Tenders, the time for which has been extended, must reach the Under Secretary for Public Works Sydney, New South Wales, not later than 30th November, 1923.
R. T. BALL,
Minister for Public Works and Railways. A 59

GREAT SOUTHERN & WESTERN RAILWAY (IRELAND).
CONTRACTS, 1923.
The Directors of the Great Southern and Western Railway Company are prepared to receive

Tenders for the Supply of the

undermentioned STORES for Three Months commencing 1st July, 1923, and alternatively for Six Months commencing the same date.

	No. of Form.		No. of Form.
Acid, Sulphuric ...	8D	Glass, Sheet, and Plate	27A
Asbestos Sheeting, etc.	40	Glass and China Sundries	27B
Baskets	10	Hardware (Sundry)	17
Bolts, Nuts and Rivets	15	India Rubber Goods	9A
Brooms and Brushes	13	Implements, Sundry	21
Brass Fittings for Carriages... ...	18	Iron Tubes and Fittings	20
Do. do. for Water	26A	Leather and Leather Goods	12
Do. do. for Gas ...	26B	Locks and Keys ...	19
Canvas and Sacks ...	6	Mats, Fibre	10
Canvas for Wagon Tarpaulins	6A	Nails	31
Carriage Laces ...	7A	Packings	40
Castings, Mall. Iron	11	Plumbago	41
Cloth for Carriages	7C	Rain Water Pipes and Gutters	26
Clothing, I.R., proofed	9B	Ropes, Twine & Flax	4
Coach Screws and Washers	15	Soaps	3C
Colours	2	Sewer Pipes, Plaster of Paris, etc. ...	32
Corks	39	Shovels, Spades, etc.	21A
Cotton Waste ...	5A	Sponge Cloths ...	5
Crucibles	41	Signal Wire Pulleys	11
Drysalteries	3	Screws and Split Pins	14
Emery and Glass Cloth, etc.	28	Tin Plates	22
Files and Tool Steel	30	Waste	5A
Fire Bricks and Clay	33	Waterproof Clothing	9B
Foundry Requisites	42	Wicks	5
Galvanized Sheets, Buckets, etc. ...	23	Wire, Fence and Signal	30A
Grates, Stoves ...	24	Wirework	30B
Grindstones	38		

Forms of Tender can be obtained on PAYMENT of 6d. each from the STORES SUPERINTENDENT, GENERAL STORES DEPARTMENT, G.S. & W.R., INCHICORE, DUBLIN. Applications for forms by Post must be accompanied by Postal Order. Stamps cannot be accepted. All enquiries for information should be also directed to the Stores Superintendent.
Patterns may be inspected at the General Stores Department on and after the 21st inst., between the hours of Ten a.m. and Four p.m. (except on Saturdays).
Tenders must be enclosed in the special envelope supplied for the purpose with each schedule, and must be posted so as to be with the undersigned before Ten a.m. on Wednesday, 6th June, 1923.
The Directors will not consider any Tender unless it is furnished on the Company's Form, and do not bind themselves to accept the lowest or any Tender.
By Order,
ROBERT CRAWFORD, Secretary.
Kingsbridge Terminus, Dublin.
May, 1923. A 538

THE SOUTH INDIAN RAILWAY COMPANY, LIMITED,
are prepared to receive

Tenders for the Supply of:—

1. STEEL RAILS and FISHPLATES,
2. STEEL BEARING PLATES for F. B. Rails,
3. LAVATORY FITTINGS.

Specifications and Forms of Tender will be available at the Company's Offices, 91, Petty France, Westminster, S.W. 1.
Tenders, addressed to the Chairman and Directors of the South Indian Railway Company, Limited, marked:—"Tender for Steel Rails and Fishplates," or as the case may be, must be left with the undersigned not later than Twelve Noon on Friday, the 1st June, 1923.
The Directors do not bind themselves to accept the lowest or any Tender.
A charge, which will not be returned, will be made of £1 for each copy of Specification No. 1, and of 5s. for each copy of Specifications Nos. 2 and 3.
Copies of the Drawings may be obtained at the Offices of Messrs. ROBERT WHITE & PARTNERS, Consulting Engineers to the Company, 3, Victoria Street, Westminster, S.W.1.
A. MUIRHEAD,
Managing Director.
91, Petty France, S.W.1,
15th May, 1923. A 567

SUNBURY-ON-THAMES URBAN DISTRICT COUNCIL

CONTRACT No. 3.

AIR COMPRESSOR.

The above Council invite

Tenders for Providing and

FIXING ONE AIR COMPRESSOR capable of compressing about 850 cubic feet of free air per minute to a pressure of 27 lbs. to the square inch, and incidental Works, in accordance with the Plans and Specifications prepared by Mr. HAROLD P. COALES, Assoc.M.Inst.C.E., the Engineer and Surveyor to the Council, which Plans and Specifications may be seen at the Council Offices, Sunbury.
Sealed Tenders, endorsed "Air Compressor, Etc.," to be delivered to the undersigned at the Council Offices on or before Four p.m. on Monday, the 4th day of June next.
The Council do not bind themselves to accept the lowest or any Tender.
E. BEECHING,
Clerk to the Council.
Council Offices,
Sunbury-on-Thames.
16th May, 1923. A 584

SUNBURY-ON-THAMES URBAN DISTRICT COUNCIL.

CONTRACT No. 2.

GAS ENGINE, SUCTION GAS PLANT, AND INCIDENTAL WORKS.

The above Council invite

Tenders for Providing and

FIXING ONE 100 B.HP. GAS ENGINE with SUCTION GAS PLANT, and incidental works at their Sewage Disposal Works, in accordance with the Plans and Specifications prepared by Mr. HAROLD P. COALES, Assoc.M.Inst.C.E., the Engineer and Surveyor to the Council, which Plans and Specifications, may be seen at the Council Offices, Sunbury.
Sealed Tenders, endorsed "Gas Engine, Etc.," to be delivered to the undersigned, at the Council Offices, on or before Four p.m. on Monday, the 4th June next.
The Council do not bind themselves to accept the lowest or any Tender.
E. BEECHING,
Clerk to the Council.
Council Offices,
Sunbury-on-Thames,
16th May, 1923. A 583

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

ELECTRIFICATION OF BOMBAY SUBURBAN LINES.

The Directors are prepared to receive

Tenders for the Supply of

certain plant in connection with the first instalment of the electrification of the above lines, namely:—

	Fee for Specification.
1. MOTOR BOGIE TRUCKS	£2
2. BONDS	£2

Specifications and Forms of Tender may be obtained at this office on and after 23rd May, 1923, on payment of the fee for the Specification, which payment will not be returned.
Contractors may tender for either or both of the above sections.
The fee should accompany any application by post. Cheques and Postal Orders should be crossed and made payable to the Great Indian Peninsula Railway Company.
Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Bonds," or, as the case may be, not later than Eleven o'clock a.m., on Thursday, the 28th June, 1923.
The Directors do not bind themselves to accept the lowest or any Tender.
The Consulting Engineers to whom applications for any further technical information may be made are Messrs. MERZ & MCLELLAN, 32, Victoria Street, Westminster, S.W. 1.
R. H. WALPOLE,
Secretary.
Company's Offices,
43, Copthall Avenue, E.C. 2,
London,
16th May, 1923. A 577

APPOINTMENTS OPEN.

Managing Director for Large

Shipbuilding, Engineering and Repairing Yard; good position for experienced man; financial interest not required.—Address, stating experience, A 478, Offices of ENGINEERING.

THE UNIVERSITY OF SHEFFIELD.

PROFESSORSHIP OF MECHANICAL ENGINEERING.

The Council of the University invite

Applications for the above

POSITION, shortly to become vacant.
Applications should be received by the undersigned, from whom further particulars may be obtained, by the 12th June.
W. M. GIBBONS, Registrar. A 535

WEST RIDING OF YORKSHIRE RIVERS BOARD.

Applications are Invited for

the POST of CHIEF CHEMIST on the staff of the Chief Inspector of the West Riding of Yorkshire Rivers Board, at an inclusive salary of £300, rising by annual increments of £25 to a maximum of £700. Some knowledge of Engineering will be an advantage. Full particulars on application.
H. F. ATTER,
Clerk and Solicitor.
71, Northgate,
Wakefield. A 440

UNIVERSITY OF BIRMINGHAM.

JAMES WATT RESEARCH FELLOWSHIP.

The Council invites

Applications for the James

WATT RESEARCH FELLOWSHIP in the Thermo-Dynamics of Internal Combustion Engines. Candidates should hold an Honours Degree in Engineering of a British University, and have had some experience in Research. The Fellowship has at present an annual value of £220, and is renewable. Applications should be sent in not later than 31st of May, 1923.
Further particulars may be obtained from the Dean of the Faculty of Science, The University, Edgbaston, Birmingham.
GEO. H. MORLEY,
Secretary. A 446

CITY AND GUILDS (ENGINEERING) COLLEGE, S.W.7.

Assistant Professorship in

ELECTRICAL ENGINEERING DEPARTMENT. Owing to the appointment of Dr. PARKER SMITH to the Chair of Electrical Engineering at the Royal Technical College, Glasgow, the Delegacy will proceed shortly to the APPOINTMENT of an ASSISTANT PROFESSOR to deal particularly with the Traction and Design sections of the Electrical Engineering Department. Candidates for the post will be expected to have had some experience of this work. Applications must be received not later than 31st May.—Full particulars can be obtained from the SECRETARY TO THE DELEGACY, The City and Guilds (Engineering) College, S.W.7. A 533

Wanted, Assistant Manager,

by well-known Gear Makers. Must have good all-round knowledge of machine-cut gearing, and previously held similar position. Age about 35 years.—Address, A 540, Offices of ENGINEERING.

General Manager Required

by Manufacturers of well-known semi-Diesel marine and stationary engine; 5 HP. to 300 HP.; selling in all parts of the world. Must have good all-round experience and connection and be a first-class salesman. Salary and commission. A splendid opening for an energetic and capable man. No investment required.—Write, in strict confidence, stating age, experience, remuneration expected, to BOX MA 52, c/o ST. JAS. ADVTG. CO., 1, Warden Street, W. A 516

Time Estimating.—Competent

MAN REQUIRED for Production Department, able to estimate accurate times on economical basis, and suggest methods of tooling, jigs, etc. Applications, stating full particulars of experience, wages, etc., in confidence.—Address, A 581, Offices of ENGINEERING.

Wanted for Sales Depart-

ment in large Engineering Works YOUNG MAN, 18/20 years of age, with good knowledge of shorthand, typewriting, French and German.—Address, giving particulars of experience and salary required, A 549, Offices of ENGINEERING.

ADMINISTRATIVE COUNTY OF LONDON.

COUNTY HALL—ENGINEER IN CHARGE.

Applications are Invited by

the London County Council for the POSITION of ENGINEER IN CHARGE of Machinery, etc., at the County Hall, at a salary commencing at £250 a year, and rising by six annual increments of £15 and a final increment of £10 to £350 a year.
The foregoing scale of salary is based on pre-war conditions and is at present subject to temporary conditions on the Civil Service scale, fluctuating according to the cost of living and making the total commencing remuneration £377 a year. The next revision of the temporary additions will take place not later than 1st September, 1923.
The person appointed to the position will be required to reside in the immediate vicinity of the County Hall, and if at any time quarters are provided for him at the County Hall he will be required to reside in them and to pay such rent therefor as may be fixed by the Council.
Members of the Council's staff are not precluded from submitting applications.
Candidates must not be less than 30 nor more than 45 years of age on the latest date for receiving applications, and unless they served with His Majesty's armed forces during the Great War must be natural born British subjects. Due weight will be given to the claims of those applicants who served or attempted to serve with His Majesty's Forces during the War.
Apply for form (containing full details) to the Clerk of the Council, The County Hall, Westminster Bridge, S.E.1. Stamped addressed foolscap envelope necessary. Forms must be returned not later than Four p.m. on 4th June, 1923. Canvassing disqualifies.
JAMES BIRD,
Clerk of the London County Council. A 536

THE SUPERSATURATION LIMIT.

By H. M. MARTIN, Wh.Sc., A.C.G.I.

IN the fifth edition of his masterly work on the "Steam Turbine," Professor A. Stodola describes experiments on the flow of steam through glass nozzles in which visible condensation of the steam was observed to occur when the actual pressure of the supersaturated steam was from 3·1 to 3·3 times the pressure corresponding to the temperature, which was 95·5 deg. C. In the present writer's "New Theory of the Steam Turbine," a formula* was derived for this ratio, according to which

$$\log_{\cdot 10} \frac{p}{p_s} = \frac{3 \cdot 75\ \sigma}{T}$$

where p is the actual pressure at which the supersaturated steam condenses and T the absolute temperature (Centigrade degrees) at which the condensation commenced, whilst p_s denotes the pressure of saturated steam at this temperature, and σ is the surface tension of water at the same temperature measured in dynes per centimetre.

The coefficient 3·75 was calculated on the hypothesis that in Mr. Wilson's classical experiments the ratio $\frac{p}{p_s}$ was equal to 8, and that the absolute temperature was 300 deg. (Centigrade degrees). These figures were taken from the *Enc. Brit.* eleventh edition, vol. xxvii, page 899. According to the tables of Kaye and Laby the surface tension of water at 95·5 deg. C. or 368·5 absolute, is about 60·4 dynes, and inserting this value in the above formula gives

$$\frac{p}{p_s} = 4 \cdot 1 \text{ nearly.}$$

This it will be seen is much higher than the figure observed by Professor Stodola, and this discrepancy led the writer to suspect that the figures taken from the *Enc. Brit.* were inaccurate, a suspicion which was confirmed on reference to Mr. Wilson's original paper in the *Phil. Trans.* for 1897, according to which the actual figures were :—

Temperature	− 16 deg. C.
Absolute temperature T	257 deg. C.
Surface tension σ	78 dynes per cm.
Ratio $\frac{p}{p_s}$	7·9
Effective radius of condensation nuclei	$6 \cdot 4 \times 10^{-8}$ c.m.

The nuclei on which the condensation came down must be, as Mr. Wilson points out in this paper, co-aggregated molecules, and would thus have the same effective radius at all temperatures. It follows accordingly from Lord Kelvin's theory, which was fully explained in the "New Theory of the Steam Turbine," that at whatever temperature supersaturated steam condenses on the Wilson nuclei, we must have

$$\log_{\cdot 10} \frac{p}{p_s} = \frac{C\ \sigma}{T}$$

where C is a constant which can be determined from a single accurate experiment.

Taking Mr. Wilson's data we get

$$C = \frac{T}{\sigma} \cdot \log_{\cdot 10} \frac{p}{p_s} = 2 \cdot 975$$

and using this value for the conditions of Professor Stodola's experiments where $\sigma = 60 \cdot 4$ and $T = 368 \cdot 5$, we get

$$\frac{p}{p_s} = 3 \cdot 073.$$

The calculated value is therefore in extraordinarily good agreement with Professor Stodola's observed values, which ranged from 3·1 to 3·3.† The agreement is quite as good as could be expected since the surface tension of water seems far from accurately determined. The values given by Kaye and Laby for σ at 15 deg. C. range from 71·4 up to 77.6, and the rate of variation with temperature as tabulated by them is also not very uniform.

Hence in compiling new tables of the properties of steam at the Wilson line to replace those given in "The New Theory of the Steam Turbine" and also reproduced in ENGINEERING of January 6, 1922, page 3, it is necessary to make a selection between these various values and to smooth out the figures tabulated to represent the variations of surface tension with temperature.

In compiling the table given below it has accordingly been assumed that

$$\log_{\cdot 10} \frac{p}{p_s} = \frac{2 \cdot 96\ \sigma}{T}$$

and σ has been taken as equal to 74·2 at 15 deg. C. Callendar's tables and formulas were used in computing the figures given.

TABLE I.—*Properties of Steam at the Supersaturation Limit or Wilson Line, Calculated from the Formula* $\log_{\cdot 10} \frac{p}{p_s} = \frac{2 \cdot 96\ \sigma}{T}$ *where* p = *actual pressure of Steam when Condensation commences,* p_s = *the Pressure corresponding to the Absolute Temperature T, and* σ *is the Surface Tension of Water at this Temperature.*

Temperature at Wilson Point, Deg. C.	Pressure at Wilson Point, Lb. per Sq. In.	Ratio $\frac{p}{p_s}$	Volume at Wilson Point, Cub. Ft. per Lb.	Total Heat at Wilson Point, Lb. Cent. Units.	Entropy at Wilson Point.	Equilibrium Temperature, Deg. C.	Equilibrium Volume, Cub. Ft. per Lb.
t_w	p_w		V_w	H_w	ϕ_w	t_s	yV_s
−10	0·3140	7·485	896·59	589·36	2·11023	18·69	973·27
0	0·6000	6·724	486·18	594·00	1·96601	29·53	526·26
10	1·086	6·074	277·99	598·58	1·91765	40·29	300·43
20	1·875	5·517	166·37	603·07	1·87388	50·96	179·48
30	3·103	5·035	103·76	607·48	1·83419	61·56	111·78
40	4·940	4·615	67·114	611·76	1·79811	72·09	72·182
50	7·602	4·249	44·831	615·89	1·76522	82·55	48·155
60	11·34	3·926	30·496	618·06	1·73527	92·90	32·700
70	16·43	3·639	21·801	623·67	1·70789	103·17	23·364
80	23·23	3·385	15·774	627·30	1·68282	113·35	16·988
90	32·12	3·162	11·642	630·72	1·65965	123·46	12·455
100	43·46	2·959	8·775	633·97	1·63850	133·47	9·378

The last column shows what the volume of the steam would have been, had it expanded in thermal equilibrium, whilst the column headed t_s shows the corresponding temperature. It will be seen that at the Wilson point the defect of temperature is about 28·7 deg. C. when the condensation occurs at − 10 deg. C. and 33½ deg. C. when the condensation occurs at 100 deg. C. The specific volume of steam at the Wilson line is very approximately 90 per cent. of the specific volume at the same pressure, but at the saturation line.

The experiments of Professor Stodola, it will be seen confirm the view, that at all temperatures the limit of supersaturation is fixed by the presence of co-aggregated molecules, the dimensions of which are independent of the temperature.

The data now most urgently required are the relationships between the pressure and volume of the steam when the expansion extends beyond the Wilson line. Mr. Wilson found in his own experiments, that in this case, the further condensation came down on new nuclei, instead of on the droplets already formed. This shows that the temperature of the steam in this further expansion must have been that corresponding to the Wilson line and not to the saturation line. This conclusion is confirmed by the measurement of the temperature of the exhaust from steam turbines, which is commonly found to be perceptibly below the saturation temperature corresponding to the pressure. Since any thermometer placed in supersaturated steam records, not the temperature of this steam, but merely the temperature of the film of moisture which condenses on its surface, the slight defect of temperature observed is no doubt an indication of a very much larger true defect. As matters stand, however, we have no information as to the relationship between pressure and volume during most of the expansion through a low-pressure turbine, but are obliged to rely on purely empirical rules.

The determination of the true relationship between the pressure and the volume of the steam during an expansion beyond the Wilson line, should not present any insuperable difficulties. All that would seem necessary is the taking of an accurate indicator diagram by optical means under conditions in which the volume occupied by the steam was accurately known at each point of the stroke. No expensive special apparatus would seem to be necessary. The cylinder need not be more than, say, 1 in. in diameter, and its base might well form the elastic diaphragm of the indicator, whilst the movement of the piston might be effected by a falling weight. In order to ensure a complete absence of moisture it would no doubt be advisable to work with steam which was slightly superheated at the outset. By jacketting the cylinder and piston with steam at the initial temperature no moisture would be deposited on these, whilst the amount of heat which could pass from these surfaces into the expanding steam during the small fraction of a second occupied by the stroke would be negligible.

* ENGINEERING, Aug. 16, 1918, page 160.

† Through a misunderstanding, Professor Stodola, on page 887 of his treatise represents the present writer as holding that the ratio $\frac{p}{p_s}$ was 8 at all temperatures, whereas in actual fact the writer contended that it must vary with the temperature, and gave (ENGINEERING, August 16, 1918, page 162) a table showing a range of values from about 11 at 0 deg. C. up to 4·3 at 100 deg. C. As the calculation just given shows, the writer would have obtained perfectly accurate values had he not been misled by the figures given in the *Enc. Brit.*

HEAVY-GRADE EGYPTIAN CRUDE PETROLEUM.

NEARLY two years ago Dr. W. F. Hume presented to the Institution of Petroleum Technologists a paper on the Geology of the Egyptian Oil Field,* the exploitation of which, first attempted in 1865, only became successful in the year 1914. A further communication on these fields was brought before the same body on the 9th inst. by Mr. W. A. Guthrie. Mr. Guthrie dealt, as the title of his paper on "Heavy-Grade Egyptian Crude Petroleum" indicated, with the crude oil, and the Institution had only discussed one paper on crude oil before. Far more is published on oil production and on the utilisation of the more or less refined products than on the crude oil. Mr. Guthrie's paper was valuable, as it gave interesting information on the properties and use of the pitch obtained from the oil for road-making.

The oilfield, in which Mr. Guthrie is working, is situated at Hurghada, on the western shore of the Gulf of Suez, and some 200 miles south-east of Suez, where an Egyptian Government Petroleum Refinery has been erected. The other, less important oil-fields of these districts are at Gemsa, nearer Suez than Hurghada, and at Abu Durba, which lies on the opposite shore of the Gulf, on the Sinai Peninsula. At Hurghada 1,201,868 metric tons of oil have been produced since 1914 from a depth of about 2,000 ft., the present weekly average rate being 3,500 tons. The oil is "wet" with about 30 per cent. of brine; but that trouble is being overcome by electric dehydration of the emulsion brought up. The oil is heavy, having a density 0·907 to 0·925 and highly viscous, and contains 10 per cent. to 11 per cent. of asphalt, 7 per cent. to 8 per cent. of paraffin wax, 2 per cent. to 5 per cent. of sulphur, and further a little vanadium and nickel; vanadium in particular is a minor constituent of many petroleums. The as yet incomplete study of the crude petroleum has to be conducted by distillation in *vacuo*, since distillation at atmospheric pressure favours decomposition; by working with a vacuum of 28 in., Mr. Guthrie has brought the vapour temperature down from 371 deg. C. to 153 deg. C. The oil is a mixture of paraffin base and asphaltic base petroleum containing hardly any naphthenes, but rich in unsaturated hydrocarbons of the olefine type. In spite of the high sulphur content the oil has rather a pleasant smell.

When commercially distilled at ordinary pressure the chief products of the oil are benzine 8 per cent., kerosene 15 per cent., residue 76 per cent.; the residue is highly viscous, so that the emptying of the barrels is a troublesome process. Originally the oil was "topped," *i.e.*, the benzene was distilled off, and the residue burnt as fuel oil. This wasteful practice can be improved in two ways, either by extracting the wax and manufacturing lubricants, or by breaking down the wax—at any rate, the wax of high melting-point—and manufacturing Diesel oil and a pitch for road-making. There being little demand for wax in Egypt, the latter method was first tried. But it was found that "cracking," to break down the wax, could not be conducted in one operation, so as to give a thin Diesel oil and a good pitch as well, because the cracking decomposed the asphalt and yielded too much free

* See ENGINEERING, October 28, 1921, page 608.

carbon, which is very undesirable in elastic pitch and also wasteful. With the aid of an ample supply of superheated steam a thin Diesel oil, free of asphalt, was, however, obtained, and this oil, which is considered too good for internal-combustion engines, can be mixed with up to 50 per cent. of residue, whilst mixtures richer in residue give a good boiler fuel.

By further steam distillation of the residue, pitch or bitumen is obtained. In the last stages particularly air-blowing may probably be substituted for steam distillation, as is done in America; but this has not been done so far in Egypt on a large scale, though in the warm climate the harder air-blown pitches would be acceptable. At Suez a hard and a soft pitch are manufactured. In making bituminous macadam the basaltic stones of sizes from 1 in. to 3 in. are heated with dry sand up to 300 deg. F. and the pitch also heated to 300 deg. or 350 deg. F., is run on the stones, 50 kg. of bitumen being used for 1 cub. m. of stones weighing 1¼ tons. A sealing coat of bitumen is finally poured on hot, sprinkled with basalt chippings and rolled down. The soft pitch is used for spraying and for painting worn macadam. So far these roads have given satisfaction.

The difficulty about the wax-extraction, to which we have referred, is that Egyptian oil, like other oils, contains the wax in the amorphous proto-paraffin condition, and not in the state of crystalline pyroparaffins which are much more easily expressed in the cold. Mr. Guthrie has, however, succeeded in isolating some wax and some lubricating oil, though the yields are hardly satisfactory. The study of those peculiar heavy oils will therefore be continued. We should mention that the Abu Durba oil is also heavy asphaltic. The Gemsa oil, which has been mined since 1908, is on the contrary a light oil of paraffin base; the differences between the oils have almost lost importance, however, because the Gemsa wells, which altogether have produced 179,400 tons, now yield hardly as much per year as Hurghada produces per week.

FLOATING PNEUMATIC GRAIN-HANDLING PLANT.

Two floating pneumatic grain-discharging plants which are employed by Messrs. Spillers and Bakers, Limited, the well-known flour millers, at Cardiff, are illustrated in Figs. 1 to 4, on Plate XXXVII., in Fig. 5 annexed; and in Figs. 33 and 34, on page 622. The plants are used for discharging ships which cannot be brought up alongside the mills, the wheat being transferred from the ocean-going ships to lighters and barges by means of the plants illustrated. Prior to their installation the work was carried out entirely by manual labour and proved slow and expensive, but since each of the plants has a capacity of 90 tons an hour, it is now possible to unload a ship at the rate of 180 tons an hour by bringing the elevators into operation together. The two plants are identical in every particular, Messrs. Spillers and Bakers having decided on two small plants rather than one large one, so that two holds of a vessel could be discharged at one time. The smaller plants are also more easily handled, and one can always be kept available in case of overhaul or dry-docking of the other.

As the amount of grain to be handled by these floating elevators was not such as to justify the installation of elaborate plant, and as the building of two small elevators necessarily cost more than would a single larger one, the design adopted has been simplified as much as was possible. The elevators were constructed by Messrs. Henry Simon, Limited, of Manchester, and to meet the conditions which were imposed by these considerations of cost the builders decided to revert to the old practice of using the ships' derricks for supporting the suction pipes and utilising the ships' winches for manipulating them. At the same time they adhered to the modern practice of employing a permanently built-up boom which could be readily swung into position over the hatches. This boom is connected with the receiver on the elevator by an arrangement equivalent to a universal joint, and when not in use lies in a fore and aft position supported by a rest on the deck of the pontoon. When the elevators are brought alongside a ship the derricks are swung out to pick the booms up and bring them into position. This arrangement dispenses with anything in the nature of a mast structure, or crane post, on the pneumatic plant itself, and the consequent reduction of top hamper enables adequate stability to be secured with pontoons of moderate beam. The plants are arranged to work side-on in order to take up as little room as possible in the dock. The grain is discharged in 1-ton lots through spouts to the barges and lighters.

The various main features of the elevators will be followed from the plans and elevations given in Figs. 1 to 4, while an excellent idea of their general appearance will be obtained from the views given in Fig. 5, subjoined, and Figs. 33 and 34, on page 622. The pipe boom is shown nested in the position on the deck rest which it occupies when not in use in Fig. 1 and in operating position over the hold of a ship in Fig. 2. This pipe boom is of heavy welded construction, and as will be seen is fitted with a stiffening truss at its outer end, where it branches into two vertical pipes. The bends are rectangular and have renewable back plates. Below the bends there are two permanently connected flexibles and about 70 ft. of combined portable steel and flexible pipe. Each pipe terminates in one of Messrs. Henry Simons' "Reform" intake nozzles. All portable grain pipes are connected together with quick coupling metal to metal joints. The inner end of the pipe boom is carried on the grain receiver, which is mounted on the superstructure on the forward end of the boat. The receiver with the pipe boom connections are detailed in Figs. 6 to 8, on Plate XXXVI. while it can be seen in most of the general views. Details of the bracket on which the swivelling joint of the pipe boom is supported are given in Figs. 9 to 11 on Plate XXXVI.

As shown in Figs. 6 and 7, a vertical pipe leads from the swivel joint into the grain receiver. This pipe is well shown in the general view given in Fig. 33, on page 622. The receiver itself is of cylindrical shape, built of plate and angles, and stiffened at the top with channel-iron framing. It is supported on the superstructure by an angle-iron ring joint and cast-iron feet. Inside the receiver there is a steel plate cylcone, with an adjustable air inlet, which delivers the dust collected from the grain to the dust seal in the substructure. The cyclone outlet pipe is connected outside to the top of the grain receiver, and from this point steel air piping with a cast-iron deck connection leads to the air receiver in the elevator compartment, which is below the grain receiver. From this point the air is carried to the inlet side of the pumps. The arrangement of the cyclone will be followed from Figs. 6 and 7. The grain and air enter together by the vertical pipe already referred to and to be seen to the right of Fig. 7. Owing to the relative diameters of the grain receiver and the pipe, the air velocity falls at the point of entry to the receiver so that the grain is no longer carried forward by the current, but falls to the base of the receiver. The lighter dust is, however, carried over the top of the cyclone by the whirling motion and is deposited inside, the air flowing up the outlet pipe and the dust falling to the bottom of the cyclone and passing through the dust seal. The air pipe from the top of the cyclone leads to the air receiver in the elevator compartment, which has already been referred to. This receiver can be seen in Fig. 1. It is built of steel plate and contains screening apparatus serving to remove any dust which may have passed the cyclone. Connection is made from it to the pumps, as shown in Fig. 1. The bottom of the air receiver is arranged for discharging the collected dust into a sack.

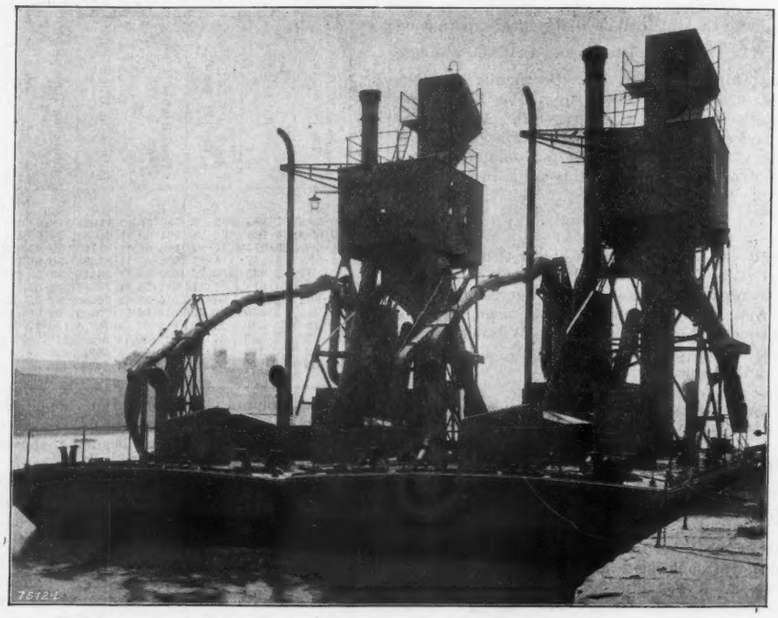


FIG. 5. STERN VIEW OF FLOATING ELEVATORS.

The grain which falls to the bottom of the grain receiver passes down through a tippler to a hopper, from which it travels to the elevator. The tippler forms an air lock and prevents the destruction of the vacuum in the receiver. It is of Messrs. Simons' standard type and consists of two compartments arranged to rock against the surface formed by the outlet from the receiver. An airtight joint is made between the tippler and the receiver by means of leather strips. Each compartment rocks in turn below the outlet from the receiver and fills with grain. While one compartment is being charged in this way the other is discharging through a side door which is rubber faced to render it airtight. The effect of the arrangement, as the tippler rocks to and fro', is that the grain is released in parcels from the receiver, while the vacuum is continuously maintained. The position of the tippler can be adjusted by means of screws fitted to the bearing blocks so that a nice working fit against the receiver base can be maintained. The tippler is rocked by means of a connection from the main engine through a countershaft which is shown by broken lines behind the air pipe in Fig. 1. This shaft is also used to drive the elevator to which further reference is made below. The drives to and from this shaft are indicated in Fig. 2. The tippler is rocked by a crank mechanism and a spring is introduced in the connecting link so that any pieces of rope, wood or iron which may be picked up with the grain cannot cause fracture of any working part. The spring mechanism allows any such obstruction to free itself without causing any damage. The dust

DETAILS OF FLOATING PNEUMATIC GRAIN-DISCHARGING PLANT.

CONSTRUCTED BY MESSRS. HENRY SIMON, LIMITED, ENGINEERS, MANCHESTER.

Fig. 27.

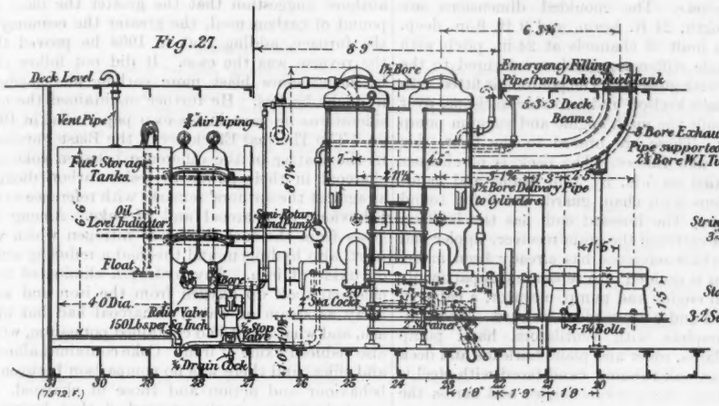
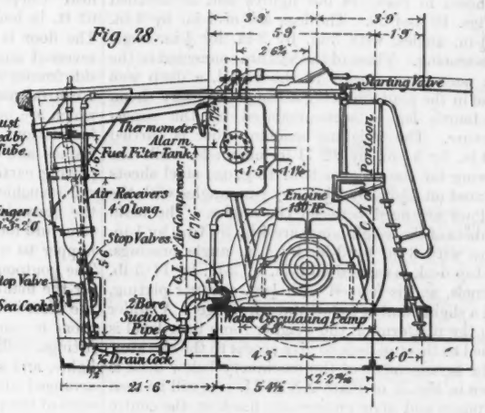


Fig. 28.



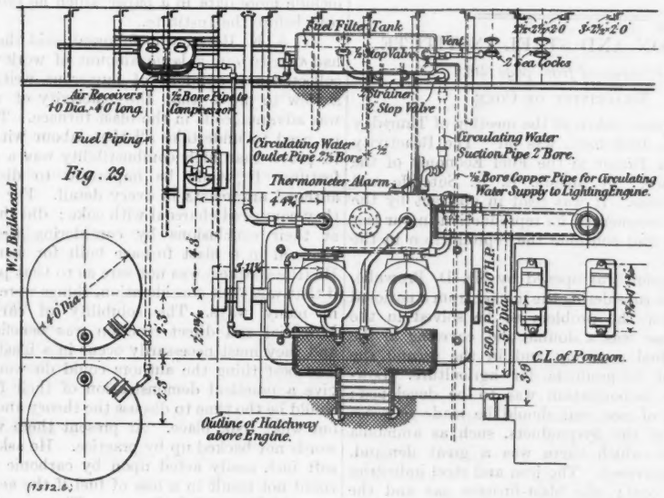


Fig. 29.

Fig. 30.

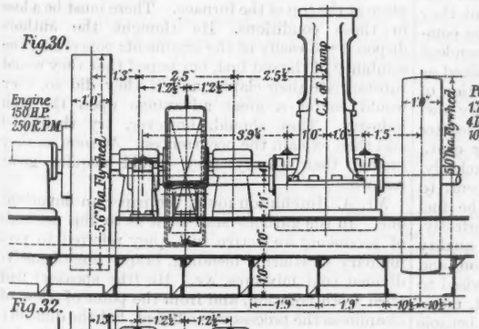


Fig. 31.

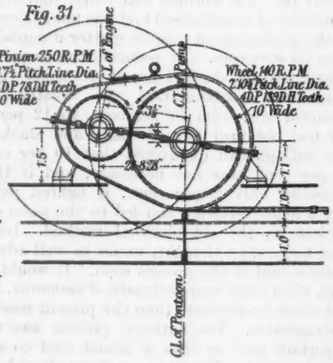
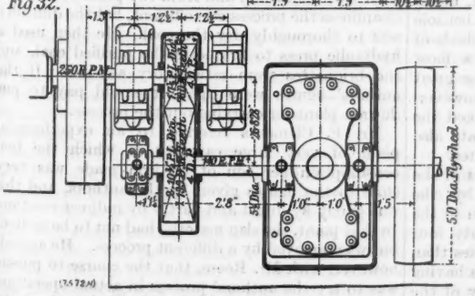

Pinion 250 R.P.M. 1·7½ Pitch Line Dia. 4 D.P. 78 Dbl. Teeth 10" Wide
C.I. of Engine
C.I. of Pump
Wheel, 140 R.P.M. 2'10½ Pitch Line Dia. 4 D.P. 152 D.B. Teeth 10" Wide
C.I. of Pontoon.

Fig. 32.



seal leading from the cyclone prevents any breakage of the vacuum at the point where the dust is removed. This seal consists of a rotating spider in a cast-iron case and removes a parcel of dust in each compartment formed between the limbs of the spider. It is driven from the same shaft which operates the tippler.

From the tippler the grain passes into a steel hopper which is built with a dust-tight deck connection and is then delivered through a rectangular chute to the bucket elevator. The chute can be seen in Fig. 1, but is better shown in the plan of the arrangement below the deck of the barge which is given in Fig. 4. The elevator lifts the grain to the top of the tower and delivers it to a hopper which is carried above an Avery 1-ton weighing machine. From this machine the grain is delivered to barges by a chute. The general features of the arrangement will be followed from Figs. 1 and 2, in conjunction with Figs. 5, 33 and 34. Details of some of the structural parts are given in Figs. 12 to 26, on Plates XXXVI and XXXVIII. The elevator boot is shown in Figs. 12 to 18, the supporting structure and the framework of the weigh-house in Figs. 19 to 22, and the elevator head in Figs. 23 to 26. The casing of the elevator, which is well shown in Fig. 34, is made from No. 10 gauge steel plates in 8-ft. sections bolted together with angle-iron joints. The boot is of $\frac{3}{16}$-in. plating and is furnished with two inspection side doors and one large door for removing and renewing brackets when necessary. This door is shown at the left-hand side of Figs. 12 and 14, and details of the fasteners are given in Figs. 15 to 18. Where the elevator truck passes through the deck a special umbrella watertight joint is provided. This joint also serves for adjustment when regulating to suit the height of the deck of the vessel. The trunking is stayed internally with cross-bolts which serve as a ladder. The chain guides are of flat steel plate carried on angle cleats all flush bolted together to avoid projections. The elevator head shown in Figs. 23 to 26, Plate XXXVIII is built of $\frac{1}{16}$-in. plate, with $\frac{1}{4}$-in. plates bolted on each side to carry the main bearings.

The elevator chain is of Ewarts' standard pattern and carries No. 20 gauge buckets at 12-in. centres. The ends of the buckets are of No. 16 gauge. The elevator has screw adjustment, and in addition is fitted with spring-loaded tension gear which allows of considerable movement of the whole of the bottom shaft in the event of pieces of hard material getting between the chain and the bottom rollers. The rollers run on a fixed shaft and are mounted on Hyatt roller bearings fitted with Stauffer lubricators. The head shaft is carried on similar bearings and is fitted with sprockets of large diameter to ensure a clean delivery. A back shaft with rollers mounted on Hyatt bearings is also provided to assist delivery to the spout. All the roller bearings are practically dust-tight. As shown in Fig. 24, one end of the head shaft projects outside the elevator casing and carries the main driving sprocket. This sprocket is driven by a Ewart chain, which can be seen in Fig. 34. The countershaft from which this drive is taken and which has already been referred to in connection with the tippler, is driven from the main pump shaft by means of a Renold chain. The drive is through a friction clutch which throws-out in the event of a choke. As is best shown in Fig. 34, the elevator head is provided with a platform for lubricating, inspection or repair work. It is reached by means of a ladder from the weigh-house top.

Grain is delivered from the elevator through a steel spout into a steel hopper above the weighing machine. This hopper is fitted with a watertight angle-iron joint bolted to the top of the weigh-house structure. The spout with the hopper and weighing machine can be seen in Fig. 1. The weighing machine is of the 1-ton Avery automatic type and discharges into a steel plate hopper which is carried by the main weigh-house structure. This hopper discharges the grain to barges through a swivelling, rocking, telescopic steel spout. The

arrangement is clearly shown in Fig. 1. When not in use the spout can be lifted up and stowed inside the edge of the vessel, as shown in Fig. 34. The main weigh-house structure is carried on four legs, as shown in many of our figures and as detailed in Figs. 19 and 20. The legs are of 4-in. by 4-in. by ½-in. angles, with 3-in. by 3-in. by ⅜-in. angle cross-bracing. Three of the legs are connected to the deck across two frames of the vessel, a deep web frame in the pontoon being arranged to carry them. The fourth leg is accommodated on the superstructure. The weighing machine floor is carried on 9-in. by 3½-in. by 22·71-lb. channels, while the covering for the weigher is of 18-gauge steel sheets mounted on 2½-in. by 2½-in. by ⅜-in. angles with the windows arranged between the angles. The main members of the weigh-house are 4-in. by 4-in. by ½-in. angles with 3-in. by 3-in. by ⅜-in. angle bracings. The top deck is carried on 6-in. by 3-in. by 14·5-lb. channels, and is formed with ¼-in. chequer plating, with a slight camber to facilitate drainage. A ladder from the platform on the weigher-room floor level is carried to this top deck to give access to the elevator.

The arrangement of the machinery below deck is shown in Fig. 4, of Plate XXXVII. As will be seen the pump and main engine are fixed on the centre line of the pontoon. On the starboard side there is an electric light engine and dynamo, and on port side the air compressor and air bottles are placed together with oil tanks and sea cock. The bucket elevator boot with the air receiver and driving gear for the tippler are arranged in a special compartment separate from the engine-room. The main engine is of the semi-Diesel type and was built by Messrs. Vickers-Petters, Limited. It has two cylinders and has been specially balanced to make it suitable for installation in a pontoon. The bedplate is also specially stiffened. The engines will run for a long period on no load without the use of lamps and without any fear of "gumming up" or other troubles which sometimes follow through incomplete combustion when running light. A water-cooled silencer is fitted and an alarm operated by a thermometer is arranged to give warning in the event of stoppage or overheating of the jacket water. Ample capacity has been arranged in the starting air receiver and duplicate compressors are provided, one driven from the main engine and one off the electric light engine. Electric ignition is used. The engine with its air receivers and fuel tanks is illustrated in Figs. 27 to 29, on page 609.

The drive to the vacuum pumps is through double helical gearing carried on extensions of the two crankshafts. The arrangement is shown in Figs. 30 to 32, on page 609, and as will be seen a flywheel is provided on each side of the gears. These flywheels are proportioned to avoid reversal of stress through cyclic variations of engine and load, and result in a more uniform pressure on the gear teeth than would otherwise be obtained. The engine is maintained as a driver under all conditions. The twin cylinder double-acting vacuum pump is of Messrs. Henry Simon's standard design, with cylinders 37½ in. diameter and 12-in. stroke. The flywheel is placed between the cylinders. The pump pistons have Ramsbottom rings and are dry lubricated so that they will run without attention for from six to nine months. The cylinders are arranged with exhaust and suction jacket on the outside, the cover and cylinder jacket being partitioned off to suit. The top and bottom cylinder covers are provided with as large a valve area as it is possible to obtain, thus rendering the pump very efficient in dealing with the air. The valves are arranged complete with seats, so that any valve may readily be removed for repair or renewal. Doors are provided in the covers for this purpose. The guide column is of the double type, and the crosshead shoes are adjustable. The big-end bearings are of the marine type and the main outside bearings of the ring-oiling type. Accessories provided in the engine-room include rotary pattern hand pumps for filling the running oil tanks from the main storage tanks, while a similar pump is provided in the engine jacket water circuit, so that the jackets can be primed by hand if required. The pump may also be used for cooling the jackets after the engine is shut down and its self-contained circulating pump consequently stopped. The electric light engine is of 8 h.p., operating on paraffin and driving a 4-kw. dynamo by belt. It is indicated in Fig. 4.

The pontoons are of all-steel construction and were built by Messrs. C. H. Walker, Limited, of Sudbrook, near Chepstowe. The moulded dimensions are 63 ft. in length, 24 ft. beam, and 9 ft. 6-in. deep. The floor is built of channels at 24-in. pitch with reversed angle stiffeners, which are secured to the side frames with gussets. The pontoon is fitted with a central main keelson and two side keelsons, over which are built the main engine and vacuum pump foundations. These are braced to the floor, side frames and web frames. The deck is of chequer plating carried on 5-in. by 3-in. beams and handrail stanchions with chain guards are fitted round the gunwale. The forward end has the built-up structure for carrying the grain receiver, tippler and hopper to which reference has already been made. The pontoon is divided into separate compartments for the main engine and pump, elevator, a cabin in the after end and a store room forward. The pontoon is complete with ventilators, hand pump fittings, bollards, roller and plain fairleads and deck lights, and an oak rubbing band faced with steel is arranged along the gunwale angles and across the ends of the pontoon.

THE IRON AND STEEL INSTITUTE.

(*Continued from page* 596.)

Reactivity of Coke.

THE first paper taken at the meeting of Thursday morning, the 10th inst., was on "The Reactivity of Coke as a Factor in the Fuel Economy of the Blast Furnace," by Messrs. E. R. Sutcliffe and Edgar C. Evans. It was read in abstract by the latter. We commenced its reproduction in our last week's issue and continue the reproduction in the present one.

The discussion was opened by Mr. D. Brownlie, who said that considering the matter from a national point of view the problem to be solved in the particular case was a double one, covering in the first place fuel economy and in the second the obtaining of by-products for agriculture. Low-temperature carbonisation was to be developed; the burning of raw coal should be made to cease generally and the by-products, such as ammonia and tar, for which there was a great demand, should be recovered. The iron and steel industries squandered coal; the blast-furnace gas and the coke-oven gas were not utilised to the extent they should be. The authors had found that the combustibility of a carbonised fuel was not so dependent on the percentage of volatile matter it contained as upon its structure. By reducing the proportion of volatile matter, the fuel ceased to smoke. By low-temperature carbonisation the volatile matter remained low, from 10 per cent. to 12 per cent., the fuel obtained burned easily and smokelessly. The authors had discovered that 10 per cent. to 12 per cent. was not necessary, and if the fuel contained only 2 per cent., it lighted perfectly, had a high reactivity and led to the same quality pig-iron as the old charcoal method. Iron and steel makers, he thought, would be well advised to make a trial of the process soon. It would, moreover, yield much more sulphate of ammonia, benzole and other by-products than the present methods of carbonisation. The authors' process was a most important one, in that it would lead to a great saving in coal. The first cost of the plant, however, was a matter for consideration, and he asked the authors to give an idea of this, and to state also whether its working was difficult to look after.

Mr. W. J. Foster disagreed with the report of the British Association Committee (quoted by the authors) in the matter of coke consumption in the blast furnace. The cost of coke was nearly four times that of slack and contained less calories than slack. The authors had quoted Johnson as having calculated that the time between the entry of the blast at the bottom of the furnace and its escape from the top in the form of gas was as short as 2 seconds; this was quite correct in certain conditions, but the time thus quoted had to be multiplied by 2 or even by 10, according to circumstances. Both the figures quoted by the authors, under the heading blast-furnace design, for the oxygen in the ore, 25 per cent., and the 10 per cent. more recently assumed by Johnson, and the question of the oxygen removal, or change, were right under certain conditions. He (the speaker) did not agree with the authors' suggestion that the greater the blast per pound of carbon used, the greater the economy of the furnace, adding that in 1904 he proved that the reverse was the case. It did not follow that by using more blast more carbon was gasified; it might be less. He further maintained the considerations he gave in his own paper read in 1904, on "The Thermal Efficiency of the Blast Furnace," in the matter of the difference between coke and charcoal in their power to resist carbon dioxide, as against the authors' remarks with reference to the behaviour of charcoal and of coke. Among the gases from the fuel there was nitrogen which was inert, also hydrogen, and this had a reducing action on oxide of iron. Any hydrogen eliminated from charcoal took up oxygen from the iron and went away as steam or water. Charcoal had but little ash, and what ash it had contained potassium, which also reduced oxide of iron. Coke contained alumina and silica, and there was no comparison between its behaviour and action and those of charcoal. In concluding, the speaker remarked that he would include more data in a paper which he proposed to read before the Institute.

Mr. A. K. Reese, who followed, said the authors had carried out a large amount of work and had collected the opinions of numerous writers, with a view to prove that the reactivity of the coke was advantageous in the blast furnace. There was no need to undertake all that labour with a view to prove that high combustibility was a desirable feature. It would be important to discuss the authors' arguments in every detail. For example, they compared charcoal with coke; did they arrive at their conclusions by considering the use of charcoal in a blast furnace built for using coke? He (the speaker) was not sure as to that point, and if that was their consideration, things were different in many ways. The solubility of carbon was beneficial and direct reaction was beneficial also, and they must necessarily occur in a blast furnace. The best thing the authors could do would be to give a practical demonstration of their fuel, then would be the time to discuss the theory and to point out what took place. At present there were only words not backed up by practice. He asked how a soft fuel, easily acted upon by carbonic acid gas, could not result in a loss of fuel if the action took place at the top of the furnace. There must be a loss in those conditions. He thought the authors disposed too easily of the arguments concerning the solubility of the old fuel, but hoped that they would substantiate their claims, and if they did so, they would confer a great advantage upon the iron industry. They should, however, try their fuel and then explain the occurrences. As soon as they proved their theory they would acquire great renown.

Mr. A. Hutchinson found the paper an important one. In the authors' statement as to the methods of producing an active fuel, they referred to preliminary treatment, blending, briquetting of finely-divided coal mixtures, &c. He (the speaker) had tried froth flotation, and from the point of view of cleanliness the process was efficient, but the difficulty was to thoroughly dry the coal. He then used a hydraulic press to briquette the purified coal, and the briquettes were satisfactory as such. If the authors' figures were right, it would pay to put down a plant for carrying out the process.

Mr. F. Clements referred to an experimental plant of very large capacity in which the fuel consumption per ton of pig-iron made was very close to the figures given by the authors, and this was partly by direct and partly by indirect reaction. In that plant, the slag material had not to be melted, but was removed by a different process. He agreed, however, with Mr. Reese, that the course to pursue was to try the authors' process in actual operation.

Mr. C. H. Ridsdale thanked the authors for instituting an inquiry into all their theories. He thought they departed a little from former remarks made by Mr. Evans. Now the matter seemed to be concerned with the cleaning of the material, and a differentiation should be made between this and the structure of the coke. He asked for records of the

BRITISH STEELWORKS GAS-PRODUCER PRACTICE.

THE PARK GATE IRON AND STEEL COMPANY, LIMITED, ROTHERHAM.

DECEMBER, 1922.

COST OF GASIFICATION.

GENERAL NOTE.

The cost of gasification has been calculated on rates as existing at the present date (December, 1922), and these have been taken as similar for similar work on both types of plant. The cost of unloading the coal from the wagons has not been included, but all other requirements have been allowed for up to the time the gas is in the main to the furnaces and the ashes are on the way to the tip.

The capacity of each plant is the same, viz., 50,000 tons of coal per annum.

Each plant is assumed to be dealing with similar coal, for example, Yorkshire Main Washed Double Nuts, containing, as charged, 3·5 per cent. of ash and 4 per cent of moisture.

	NON-MECHANICAL PLANT. Item of Cost.	Per Annum. £ s.	Per 1,000 Tons. £ s.	MECHANICAL PLANT. Item of Cost.	Per Annum. £ s.	Per 1,000 Tons. £ s.
1	*Capital Cost :* 17,250*l.* Depreciation at 7½ per cent. ..	1,294 0	25 18	*Capital Cost :* 24,000*l.* Depreciation at 10 per cent. ..	2,400 0	48 0
2	*Labour :* Men required Each shift : One charge hand Three gas men Two cellar men Day shift : One coal man One labourer Total cost at current rates	3,350 0	67 0	*Labour :* Men required Each shift : One charge hand Two gas men Day shift : One crane man One labourer Total cost at current rates	1,900 0	38 0
3	*Repairs*	112 10	2 5	*Repairs*	175 0	3 10
4	*Power :* Coal elevator and Conveyor = 250 units at 1*d.*	52 10	1 1	*Power :* Grates and agitators = 1,200 units Crane = 300 units = 1,500 units at 1*d.*	312 0	6 5
5	*Stores, &c.*	75 0	1 10	*Stores, &c.*	125 0	2 10
6	*Establishment Charges*	50 0	1 0	*Establishment Charges*	50 0	1 0
7	*Carbon discharged with Ashes :* Allowing 4 per cent. of ash in coal, and 25 per cent. of carbon with ash. Weight of carbon = 14 tons at 1*l.* .. (Per 1,000 tons of coal)	700 0	14 0	*Carbon discharged with Ashes :* Allowing 4 per cent. of ash in coal, and 10 per cent. of carbon with ash. Weight of carbon = 4·5 tons at 1*l.* .. (Per 1,000 tons of coal)	225 0	4 10
		5,634 0	112 14		5,187 10	103 15

impurities in the irons produced, and referred to his own former work in regard to the reduction and stated that this occurred at the tuyeres or close to them. He agreed in the matter of the great sensitiveness of the hearth, and more combustible coke would lead to economy. What was hindering, he asked, the making of a practical trial ?

In the course of their reply, Mr. Evans said they realised that the process had to be proved in practice, and Mr. Sutcliffe added that this required funds, without which nothing could be done. There was twelve years of solid work behind the process, experimentally only so far, and for a practical trial a plant would be required that would render available a few thousand tons. A plant yielding 300 tons per day would cost about 120,000*l.* He added that they would reply fully by correspondence.

BRITISH STEELWORKS GAS-PRODUCER PRACTICE.

The second paper taken at the meeting on Thursday morning was on the subject of "British Steel-works Gas-Producer Practice," by Mr. F. Clements. We reproduced this in abstract on page 597 of our last issue, and reproduce in this issue the sheet No. 15 of the author's comparisons between a non-mechanical and a mechanical plant.

Mr. H. M. Ridge thought Mr. Markham, chairman of the Park Gate Iron and Steel Company, deserved the thanks of the Institute for allowing such complete data as those given by the author to be issued. He added that the author called attention to the undecomposed steam passing with the gas from the producer into the furnace; this was detrimental, and it had no useful effect in the furnace. But his (the speaker's) main point in this connection was that the object in view could be arrived at differently. An increase in the amount of steam delivered into the producer gave results which were not always satisfactory, and it was desirable not to rely too much upon the steam, but to replace its action by blowers. Steam or water vapour should be used only to prevent the clinkering of the ash. He (the speaker) did not succeed in reducing the steam except by the use of an auxiliary blower. He asked the author how he determined the saturation limit of the gas, and

COMPARISON OF PLANTS.

GENERAL NOTE.

The comparison is drawn up with a view to stating concisely the relative merits of the two types of plant from a constructional and operating point of view.

The plants are again taken to be dealing with a similar class of good coal, as experience shows that no design of producer works with equal satisfaction on low-grade coal.

	Particulars.	Non-Mech. Plant.	Mech. Plant.	General Remarks.
1	Capacity of producer per unit	1,000 lb. per hour	2,400 lb. per hour	The considerably smaller ground space occupied by the mechanical plant is often an important advantage, especially where a larger gasification is wanted in an existing works where space is limited. At the same time it should be noted that the non-mechanical plant includes one spare unit as stand-by, whilst the whole of the mechanical units are in service. The laying-off of one of the six units therefore reduces the gasifying capacity by 16·6 per cent.
2	Number of units per battery	16	6	
3	Working hours per week	150	150	
4	Capacity of plant per week	1,000 tons	1,000 tons	
5	Total ground area occupied	4,540 sq. ft.	2,610 sq. ft.	
6	Class of coal ..	Bituminous	Bituminous	Both plants are assumed to be working on similar classes of good coal. Experience shows that, whilst mechanical producers are better able to deal with low-grade coal than non-mechanical, yet in all cases it is the best policy to use the best coal available. This is confirmed by the comparative schedule on sheets Nos. 11, 12 and 13.
7	Method of handling coal	Elevator and conveyor	Crane and grab bucket	In both cases the coal is unloaded from the wagons by hand, it being assumed that the plants are supplied with coal already graded. If run of mine coal is used then crushing plant should be installed. The crane and grab bucket is convenient for loading the ashes as well as handling the coal, but the electrical units used per 1,000 tons of coal dealt with is higher than with the elevator and conveyor. It must not be overlooked that the weight of the grab forms a considerable dead load on the crane.
8	Power consumption	250 units	Grate and agitators, 1,200 units ; crane, 300 units	
9	Capacity of Bunkers	20 tons	24 tons	The capacity of the bunkers on the non-mechanical plant represents 48 hours' supply, whereas the mechanical plant is only 24 hours' supply. This capacity is important, especially in works where shunting is liable to interruption. In the mechanical plant the large ground bunker assists in forming a coal storage.
10	Character of ash	Non-clinkering	Non-clinkering	The character of the ash (clinkering or non-clinkering) is of vital importance since it governs largely the amount of steam used with the blast. When the ash has any tendency to clinker then hand-poking is found necessary in all types of producers.
11	Carbon discharged with ash	25 per cent. with ash	10 per cent. with ash	If little or no hand-poking is needed then, with care, the proportion of carbon discharged with the ash is less from a mechanical than a non-mechanical producer.
12	Rate of gasification per hour of dry coal per sq. ft. area	20 lb.	32 lb.	
13	Method of blowing producers	Steam jet	Steam jet	The use of fans for providing the air blast is now being superseded by steam air injectors of more scientific design which not only automatically give the correct mixture, but render each producer independent. The steam air injector has also the advantage in that it is impossible to shut off the steam without shutting off the air also.
14	Saturation temperature	55 deg. C.	45 deg. C. to 70 deg. C.	The saturation temperature is naturally determined by the character of the coal used. It is the best practice to keep this as low as consistent with the regular working of the producer, not only because of the better quality of the gas, but also because of the saving in steam.
15	Steam used per lb. of dry coal	0·33	0·30 to 0·95	
16	Steam used per hour (in lb.)	5,400	4,320 to 13,680	
17	Method of charging producer	Intermittent by hopper, 200 lb. each 12 minutes	Continuous	For regular work the continuous is advantageous, but the intermittent feed is also useful because it permits of any sudden fluctuation in gas demand to be quickly met.
18	Poking producer	By hand	Agitators with hand assistance when necessary	The installation of agitators which keep the surface of the bed level and free, are a considerable help in maintaining a constant supply of gas or regular quality. Hand-poking, when properly carried out, gives good results, but calls for considerable skill on the part of the attendants. All plants on which hand-poking has to be done should be equipped with steam-blown poking holes, similar to that shown on sheet No. 1. This is essential in order to prevent discomfort to the attendants, and also enable them to see their work. The saving of gas effected by such fittings is very considerable.
19	Analysis of gas by vol. CO_2	6·5	4·0	With reasonable care and attention it is possible to produce gas from non-mechanical units equal to that from mechanical producers. As this care, however, depends upon the human element the mechanical producer can be more relied upon for regular quality.
	CO	24·0	28·0	
	H_2	11·6	13·5	
	CH_4	5·1	3·41	
	N_2	52·8	51·09	
20	Calorific value C.H.U.'s.	1,386	1,442	
21	Capital cost of plant	17,250*l.*	24,000*l.*	
22	Repairs per 1,000 tons of coal gasified	45*s.*	70*s.*	The repairs on the mechanical producer largely depend on the care of operation, because if the ash is discharged too rapidly the position of the hot zone is lowered and envelopes the blast cone, which then requires renewal. Unfortunately the cost involved then becomes considerable. As will be observed from the schedule on sheet No. 13 the cost of repairs varies materially as between the different plants.
23	Gasifying cost per 1,000 tons of coal	112*l.* 14*s.*	103*l.* 15*s.*	

for further data on his formulæ giving the mean specific heat.

Mr. B. Talbot referred to his work at Pencoyd for the introduction of producers, for even in the United States it was found at the time that the fuel was getting worse and labour becoming unsatisfactory. Considering the fuel available at Park Gate, he (the speaker) did not think he would have gone in for a mechanical producer. The fuel available in Durham contained 20 per cent. more ash, and trials with that fuel would throw up the difference between mechanical and hand producers. When all considerations were taken into account there was a great superiority in the mechanical plant over the hand one. But coke-oven gas was, he hoped, the fuel the use of which would be developed more and more in the steel furnaces.

Mr. F. W. Harbord emphasised the great importance of fuel economy, adding that the difference in the results of mechanical and hand producers lay in the quality of the fuel available. For his part, he was looking forward to the time when it would be possible to do away with producers altogether, but even then one might be worse off in some respects.

Mr. W. H. Patchell said he had been responsible for the putting down of a 60-ton plant to produce gas; this was during the war, and it was decided to make it non-mechanical, but the plant produced ash, and it ought to have been decided to make the plant a mechanical one. As had been stated, the matter rested with the quality of the fuel, and if good men could be had and also good fuel the hand producers gave satisfaction.

Mr. Cosmo Johns found the author's conclusions interesting and in agreement with those of Professor Bone and Dr. Wheeler, and with those he (the speaker) also gave. There were differences in working the producers, the fuel could be introduced by hand or by a skip, a poker could be used or there might be a rotating grate, the feature of mechanical producers being the latter device. Further data taking these points into consideration would be interesting.

Mr. A. H. Lymn stated that the author had taken in all cases the gross calorific value of the gas, and not the net, which latter, he thought, was the one to take for the value of the gas. Did he also take the gross calorific value of the coal? The value taken for this should also be the net. In regard to moisture the author had raised the steam required under pressure in an external plant and added it to the air blast, and he (the speaker) asked how he checked his figures in this connection. The thermometer had been located directly underneath the injector; this should have been placed in a piece of piping and be under the influence of the mixture. He also asked how the author arrived at the volume of gas; the proportions he took for tar and soot appeared to be rather high. A definition should be laid down as to what was meant by "the efficiency of a gas producer." The author had stated that at the higher saturation temperatures the quality of the gas was reduced, and the amount of free moisture carried was excessive, but if he had increased the fuel further he would not have had that result. He (the speaker) gave the analysis of the gas he obtained with Yorkshire Bentley nuts; its gross calorific value was 200 B.Th.U., the net 183 B.Th.U., and was of very suitable composition for use in the steel furnace, and compared favourably with the authors. The by-products recovered reduced the coal bill by 10*s.* per ton.

Mr. George, a visitor from the United States, said that both hand and mechanical producers could be met with in America, but practically no new hand plant were being put down, and had not been put down for the last four or five years. The greater cost of coal and of labour put the hand type out of the running. The use of producer gas in the United States was not increasing at any very great rate. Mixtures of tar and coke-oven gas were being used in the open-hearth furnace, and by-product recovery coke ovens were being put down rapidly. Oil was also being used as a fuel for the open-hearth. The mechanical producers which were being installed in some works were for replacing the older hand types.

Mr. J. A. Smeeton stated that the author had proved the efficiency of producers and his experiments would be useful; they were carried out under ideal conditions and with an ideal fuel, whereas the fuel was generally indifferent. Fixed grate producers had had their day, and we had followed other nations in installing producers having a rotating grate.

Dr. W. H. Hatfield said the composition of the gas was an essential feature, and he would like to know whether the compositions were average ones, indicative of the general results obtained from the producers of the different companies, how many tests were made and over what period the averages were taken. He (the speaker) referred to Mr. Smeeton's last remark, and said that comparing American practice with that of Messrs. Steel, Peech and Tozer, it would be found that the combustibles in the American gas were about 35 per cent., whilst in this country we were getting up to 42 per cent. In this country also we had been successful in satisfactorily obtaining the temperatures right throughout the bed, and the gases on leaving the producer were at 600 deg. The maximum temperature in the producers at about 3 ft. 9 in. below the surface level of the coal was 1,125 deg. C. The author would agree that the 1,400 deg. he gave and the 1,125 deg. pointed to a variable in producer practice which was worthy of more study.

Mr. W. H. Patchell here remarked that there was a Joint Committee now sitting at the Institution of Civil Engineers which had the question of heat engine trials under review. Gas producers, he thought, came in that question. He was a member of that committee, and would be glad if it could be arranged for them to be included.

In the course of his reply, Mr. Clements said he was not inclined to take Mr. Lymn's use of the net calorific value of the gas, as it was an essentially unscientific basis. The net value in England was different from what it was in Germany, and that was again different from what it was in France. It was an arbitrary figure. He agreed that there ought to be some definite basis for the efficiency of the gas producer. On the other hand, the efficiency did not vary, since if one had a low-grade gas in calorific value, there would be a very much larger volume, and the actual amount represented in the gas was practically the same throughout all the conditions. That had to be correlated with the effect in the furnace, but for the present he did not see his way at connecting the two. The compositions he gave were average values over long periods, and they could be taken as representing usual working conditions. In regard to temperatures, no tube could be got to stand the highly oxidising conditions in the producer. Dr. Hatfield may have obtained the figures he quoted, because the producer was receiving a highly saturated blast, or time was not allowed for equilibrium temperature in the various zones. He was unbiassed in regard to hand or mechanical producers. He was in favour of the best thing. In a new plant, he would put down mechanical producers. The present paper was the last of a trio, the object of each of which was heat economy. (See ENGINEERING, vol. cix, page 646, "British Blast-Furnace Practice"; vol. cxiii, page 579, "British Siemens Furnace Practice.") The work had been followed with attention in France, Italy and Germany, and especially in the United States. Mr. Clements then gave records at Parkgate of ingots produced and coal used at the producers over three periods. The coal per ton of ingots was 5·33 cwt. in 1919, 4·92 cwt. in 1922, and 4·59 cwt. in 1923; these results were over the whole output of the shop. It was on such lines as these that lay the prosperity of the steel industry.

MOULDING SANDS.

The last paper taken at Thursday morning's meeting was "On Some Characteristics of Moulding Sands and their Graphical Representation," contributed by Mr. J. E. Fletcher, who read it in abstract. In this the author described his subsidence methods of testing the sands, and gave the curves obtained for various grades. He had found the methods useful also in examining the nature of "used" sands, and of mixtures of new with "used" sands; further, they had proved of some considerable practical value and had been used in giving advice to a number of the members of the Cast-Iron Research Association.

The chairman announced that the paper would be discussed by correspondence.

TIN IN STEEL.

The first paper taken on the afternoon of Thursday, the 10th inst., gave "Some Observations on the Effect of Small Quantities of Tin in Steel," by Mr. J. H. Whiteley and Mr. A. Braithwaite. It was read in abstract by the former. The paper showed that the presence of small percentages of tin in medium carbon steel was liable seriously to impair its ductility; in rails, even 0·06 per cent. might be unsafe. The harmful effect of tin apparently increased with the carbon content, for in mild steel the above amount apparently had no detrimental effect. The degree of brittleness produced by tin appeared to be influenced also by the heat treatment given. In investigating the effect of tin, factors such as the finishing temperature and the amount of work applied to the metal in rolling and forging should not be overlooked.

As the time for discussions was short, the chairman suggested that this contribution should be discussed in writing.

SINGLE METALLIC CRYSTALS.

The second paper taken on Thursday afternoon was on "The Production of Single Metallic Crystals and Some of their Properties," by Professor H. C. H. Carpenter, who read it in abstract. We commenced the reproduction of this paper on page 579 of our last issue.

The discussion was opened by Professor C. H. Desch, who, on rising, was heartily congratulated, on the motion of the chairman, upon his nomination as a Fellow of the Royal Society. Professor Desch found the work described in the paper to be of very great value in that it gave an indication of what were the real mechanical properties of metals. There were now available definite measurements of certain mechanical properties of single crystals; an extension of the work to two and more crystals might perhaps afford a means of studying what occurred at the boundaries. Polanyi, in Germany, had carried out work on textile fibres and had extended this to wires and metals. He had made a single crystal in the cast condition, and had carried out measurements on tin, lead, zinc, &c. Zinc in the cast condition was a brittle metal. He showed on the blackboard how in a zinc rod slipping took place in one plane only, the basal plane, the slips retaining their parallelism. The interesting point was that when tilting went on to a certain extent, up to a definite angle, then rupture would occur. He pointed out how at certain angles the material showed itself very brittle. The occurrences in zinc in some cases were more simple than in aluminium. He hoped that data like those of the author would be secured for iron, copper and other metals.

Dr. W. H. Hatfield found the work carried out by Professor Carpenter and Miss Elam to be the most important contribution to metallurgy which had been made for many years. The properties of metals had been greatly discussed and refuge had repeatedly been sought hitherto in arguing that hypothetical film between crystals, which whether it existed or not was still open to question. Owing to the present paper, one was now in a much better position. It was true that the metal in this instance was only one metal, aluminium, but it was surely safe to argue from one metal to another, to reason by analogy and say that something similar occurred in the case of iron. Instead of trying to explain the properties of metals from an hypothetical basis, there was now a fact to go upon, and he felt that the material which constituted the crystal itself was that which was of the most interest.

Colonel N. T. Belaiew found that the paper, besides rendering one now able better to deal with the mechanical properties of metals, gave a better insight as to their inner structure.

Mr. E. H. Saniter said that the possible application of similar conditions to iron was one which greatly appealed to him. In drawing down steel to wire, it was customary to "patent" the material, that is to say, to heat above the critical point and cool through the critical range for greater ease in drawing. Patenting gave a coarse crystal. There might be a possibility of introducing a variation in the process

and perhaps to produce the required results by low-temperature patenting.

Professor C. E. Edwards found the paper to be of very great practical importance. In tin plate steel sheets, where it was necessary to have recourse to deep stamping, large crystals were produced, ½ in. in diameter, and the surface subjected to the dishing gave corrugations in the dished article, similar to the occurrences in some of Professor Carpenter's test pieces. He (the speaker) had to study the condition of this crystal in practice, and in that connection the work of Professor Carpenter and Miss Elam was of inestimable value. He was able to reproduce that crystal and to get the corrugations synthetically in a mild steel plate; they were much the same as described in the paper. (Here Professor Edwards exhibited a mild steel strip as an illustration, in which the crystal went through the whole thickness.) When in a tin plate there was surface decarburisation, the crystal was on the surface and was prevented from growing through the thickness by the carbide of iron present, which acted as a barrier to the crystal growth. When no such barriers existed the crystal growth through the thickness was not impeded.

Miss C. F. Elam said she was aware of the work carried out by Polanyi, and although zinc had a different crystal structure, the work on aluminium could apply to other metals. In all the experiments all the crystals showed slipping in two planes, and the crystal axis altered with regard to the axis of the test-piece. She was greatly interested in Professor Edwards' crystal of iron.

Professor Carpenter, in replying briefly to the discussion, was glad that Dr. Hatfield had emphasised the fact that it could now be said definitely that a metallic crystal had such and such properties, and that the paper had brought together a range of facts. The occurrence did not seem to be connected in any way with the "amorphous film," if this existed. It was clear that the work referred to in the paper would have an application fairly soon.

True Steels.

The last paper taken on Thursday afternoon was "The Correlation of the Chemical Constitutions of 'True Steels' with their Micrographic Structures," by Professor J. O. Arnold, who read it to the meeting. This paper we shall reproduce in a future issue.

The discussion was opened by Sir Robert Hadfield, who welcomed the paper as a reminder of the work which had been carried out in the past. Most of the steels that were referred to were now being currently produced. The remarks made as to manganese steel were quite correct and this still held its own.

Dr. Hatfield said the paper gave the result of Professor Arnold's life study of the constitution of steels. He (the author) spoke of "true steels," which some would call "eutectoid steels." In regard to stainless steel, he (the speaker) thought that although the work of Professors Arnold and Read had laid solid foundations to our knowledge, it was left to Mr. H. Brearley at a later date to discover that the 14 per cent. aluminium steel was stable. The work by Professor Arnold and Mr. Knowles in regard to manganese steel had been largely lost sight of, but their series was a very interesting one and it would repay readers to reconsider their joint paper on these alloys.

Professor F. C. Thompson said he was very glad to agree with Professor Arnold's work in regard to the separation of carbide and to the tungsten and cobalt series, the conclusions arrived at and on which he had some doubts at first having been substantiated.

Colonel Belaiew brought the testimony of the late Professor Tschernow to the importance of the work carried out by Professor Arnold in metallurgy, and called attention to the metallurgical researches made in the eighteenth century in France by Guyton de Morveau and in England by Priestley.

Professor Arnold announced that he would reply by correspondence.

Dinner of the Institute.

The annual dinner was held at the Connaught Rooms on Thursday evening, and proved a most successful function, at which Mr. Francis Samuelson presided over a company of about 400. In reply to the toast of "The Guests," proposed by Sir William H. Ellis, the Right Hon. John Hodge, M.P., made a very happy speech in which he suggested that the iron and steel industries should organise themselves politically. He found an appreciative audience for his criticism of the lack of patriotism shown by some of the railway companies in purchasing steel tyres and other material from abroad. Lord Gainford had something to say about the effects of high railway freights on trade, in proposing the toast of "The Iron and Steel Industries." In reply, Sir Frederick Mills spoke of the effects of the international rates of exchange on industrial development and made a plea for better trading relations between the family of nations comprised in the British Empire. Lord Gisborough proposed the "Institute," and the president, Mr. F. Samuelson, replied by referring, in an interesting speech, to the expansion of the Institute and its growing numbers in all the countries of the world.

The members reassembled on the morning of Friday, the 11th inst., when the proceedings opened by the announcement by the secretary of a number of Carnegie Research Scholarships.

Electrical Power in Iron and Steel Works.

The first paper taken dealt with "Economic Principles Governing the Use of Electrical Power in Iron and Steel Works," by Mr. C. A. Ablett, who read it in abstract. In this, the author reviewed the source of power under four headings, namely, power produced by the works themselves from natural resources available within the works, that produced by the works from exhaust steam, that produced by the works from fuel, and that purchased from an outside source. He also gave a section on the utilisation of power for driving rolling mills. His cost of power with a steam-turbine plant and gas-fired boilers was 0·20*d.* per unit at 65 per cent. load factor and 0·57*d.* per unit at 21·5 per cent. load factor; the corresponding figures, the boilers being coal-fired, were 0·42*d.* and 0·86*d.* respectively. Using a slow-speed gas engine plant, the respective figures were 0·29*d.* and 0·82*d.* The author called attention to the risk surrounding the use of an exhaust steam turbine; this tended to perpetuate obsolescent reciprocating engines, and one was not justified in considering exhaust steam a natural heat resource of a works—in fact, he added, it was an asset of more than doubtful character.

Mr. Walter Dixon thought the author was to be congratulated for putting forward his paper, which was of an economical rather than of an engineering character. The figures for working at various load factors were interesting, as also were the remarks concerning the exhaust steam turbine; this did good work, but was liable in the long run to lead to disaster economically. With reference to gas engines the fact should never be lost sight of that although gas might be available, a steel works was essentially a works for the making of steel. The paper was full of self-evident truths, but there were many points not quoted which would combine together to influence a decision. Again, one could buy sometimes more cheaply than one could make, but the application of this fact depended upon how far it was wise to do so, or not.

Mr. F. Clements, referring to the author's figures for high pressure steam turbines and gas-fired boilers, compared with gas engines, said these depended upon the size of the plant considered, also upon the class of the installations. Did the author allow for spare units? He (the speaker) did not understand the cost of water, oil, stores being 0·02*d.* with the high-pressure steam-turbine plant, and 0·03*d.* for the gas-engine plant for the same load factor. Did he include, in the steam plant, the boiler-water preparation and dealing with the condensed steam? In Belgium, Messrs. Cockerill had been very successful in running gas-engine units up to 6,000 kw.; these to his (the speaker's) mind were hitherto unsurpassed, and in these engines the gas pressure was increased to 85 lb. With much larger units the cost of working a plant was much reduced.

Mr. L. Rothera emphasised the advantage of electric drive for rolling mills owing to the easy regulation to counteract frictional losses. An electrical installation had, further, to be considered in its entirety.

Mr. F. Anslow thought it was well to emphasise the importance of the load factor; this should be a foremost consideration. Many who had charge of works' management were not sufficiently aware of its importance, and it was right that the author should have given prominence to it. It came in specially in the utilisation of exhaust steam. Many steel works were connected up with collieries, and a colliery load factor was not as good as that of a steel works; it would be below the figures stated by the author. Powdered fuel was going to be a great asset in a steel works, but from the point of view of the load factor it would have to be resorted to only after full consideration of the problem in every aspect.

Mr. A. Hutchinson found the paper to be a very full statement of the case.

Mr. Ablett, in replying, said that he had been compelled to give his contribution a reasonable length, and it was difficult to present a paper which was not too long. In regard to the size of the installation, in his comparisons referred to above for two load factors, he had assumed 6,000 kw. of plant in actual running, with an addition of 50 per cent. as reserve, equal to a total of 9,000 kw. The capital charges were reckoned on this latter total. In the matter of water, oil, stores and other charges, these had been brought down to the nearest second place decimals. In the case of the water, this had been assumed fit for the boilers, and the cost of condensing water had been included. The type of Belgian gas engines referred to, working at increased temperature in the cylinders, would result in cheapening the cost of power. In regard to improving the load factor it was difficult to make any general statement because the opportunities for doing this varied greatly in different works.

Steels Containing Globular Cementite.

The second paper taken on Friday morning was on "Some Properties of Steels containing Globular Cementite," by Professor C. H. Desch and Mr. A. T. Roberts. It was read in abstract by the latter. The work it dealt with was undertaken to determine certain properties of high-carbon steels in which the cementite had been brought completely into the globular condition by combined thermal and mechanical treatment. It dealt with the effect of heat treatment on a carbon steel having 1·28 per cent. of carbon, slowly cooled from the molten state and heated under such conditions as to produce globular cementite. It also described experiments on the steels used in the manufacture of safety razor blades and gave an account of the factors which determined their efficiency.

Professor F. C. Thompson welcomed the paper in that it gave the death blow to the Japanese heresy to the effect that the production of spheroid pearlite depended on taking the material to a temperature above the Ac1 point. To English metallographists this had always appeared unnecessary, and the paper showed this quite definitely to be so. From that point of view only, the paper was one of great value. The technique displayed by the authors in their micrograph No. 10 showing the grain structure in "spheroidised" steel at a magnification of 1,500 represented a great advance. The authors' statement to the effect that on the temperature being raised the boundaries became more and more straight—namely, that the irregularities of the crystals disappeared by heating at a high temperature—was a point also clearly shown in his (the speaker's) paper written in conjunction with Mr. L. E. Benson for the present meeting. The evidence put forward by the authors in regard to the impact value in conjunction with the occurrence of coalescence was a most interesting one, and to him (the speaker) quite unexpected. Their statement as to the temperature above the Ac1 point required to cause large masses of pearlite to pass in solution, taken by itself, was insufficient, and so far as he could see, there was no reason to believe that at the cementite line the whole of the carbide would go into solution; the time factor, it should be remarked, operated to a considerable extent.

Professor C. A. Edwards said the authors had given two diagrams, A and B, in which they had marked

UNIVERSAL BAR COAL-CUTTER.

CONSTRUCTED BY MESSRS. MAVOR AND COULSON, LIMITED, ENGINEERS, GLASGOW.

(For Description, see opposite Page.)

Fig. 1.

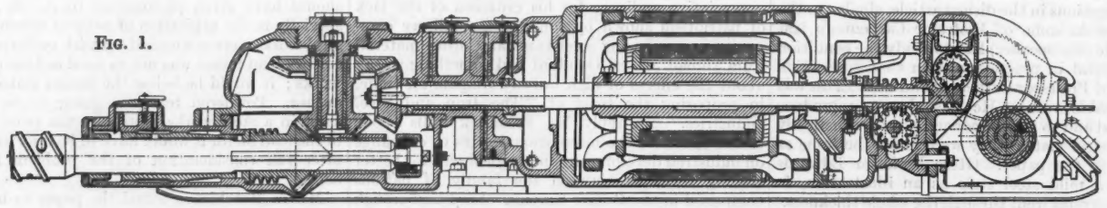
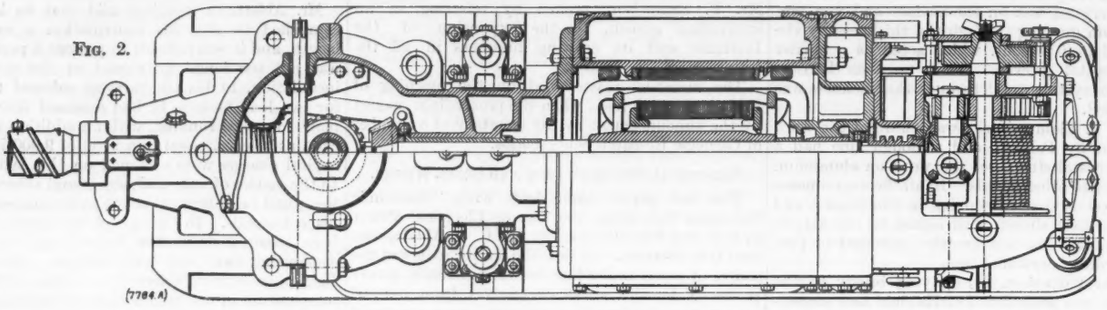


Fig. 2.



Figs. 1 and 2. Sectional Elevation and Plan of Bar Coal-Cutter.

dotted lines to indicate how coalescence occurred. To him it seemed rather remarkable that two or three isolated globules should coalesce unless it were stipulated that the intervening phase dissolved one of the constituents.

Mr. J. H. Whiteley found the micrographs most excellent. That cementite had a low impact value was known, and the reason was stated in the paper by Professor Thompson and Mr. Benson, written for the present meeting. With reference to coalescence, he (the speaker) had had photographs showing particles of cementite in contact and no coalescence taking place. He asked whether the authors found difficulty in using the sodium picrate etching solution.

Colonel N. T. Belaiew explained on the blackboard the relationship between the globular cementite and the structure of Damascene blades. Several of the authors' micrographs showed the structures that were arrived at unconsciously in India and Persia many years ago with the very crude means then available.

Dr. Hatfield found it rather difficult to accept the authors' theory as a convincing explanation of the reason why a razor did not cut at times. He called attention to the manganese content in the steels relatively to the carbon content; Steel A, carbon 1·28 and manganese 0·8; steel B, 0·2 and 0·45 respectively; steel C, 0·45 and 0·55 respectively. Low carbon, with high manganese, and the reverse, would have given a useful means of comparison.

Professor Desch said the photomicrographs were the work of Mr. Roberts. With regard to Colonel Belaiew's remarks, the reason why they did not obtain the Damascene steel structure was due to the initial structure and condition of the ingot which were not satisfactory for that. Forging with a view to obtain the Damascene structure was a tedious process. The explanation for the impact value was not to be found in the grain size. No etching difficulty was experienced with the sodium picrate, this was regularly used. They did not deal with the ordinary razors, only with safety razor blades, which was a different and more complex matter, but they could distinguish at once a good from a bad blade. The evenness of the distribution of cementite particles came in; in good blades the distribution was uniform and the particles were of uniform size. This distribution depended upon the distribution of cementite in the original strip. It was well known that the best blades of American make came from strips manufactured and rolled in Sheffield. He

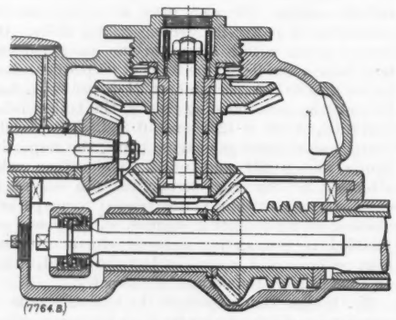


Fig. 3. Gear Drive from Motor to Cutter Bar—Disengaged.

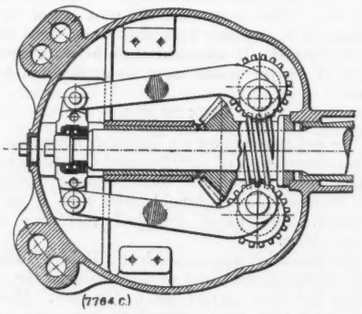


Fig. 4. Mechanism to Reciprocate the Cutter Bar.

agreed with Dr. Hatfield that it would have been preferable had the manganese content been more uniform and regular, but the research was to throw light on certain points and the materials of which the analyses were given were taken from store at the University.

Basic Slags.

The third paper had for its title "The Constitution of Basic Slags: Its Relation to Furnace Reactions"; it was contributed by Mr. T. P. Colclough, who read it in abstract. It reviewed melting, working and tapping slags, the effect of slag composition on the rate of elimination of metalloids, the distribution of manganese and the elimination of sulphur.

Mr. E. H. Saniter found the paper to be a plain statement of facts which would be useful to steel-makers. He thought the author insisted too closely on the action of lime, since oxide of iron was also a strong base. In working molten metal to reduce the carbon, phosphorus could return to the metal, and at this part oxide of iron played a great role. He (the speaker) could not accept the author's explanation in regard to sulphur, where he said that manganese acted in the furnace as in the mixer, for there was a great difference between the temperature in an open-hearth furnace and that ruling in a mixer. Manganese sulphide could not exist at the temperature of molten steel in the furnace; it was formed at a temperature close to the solidification temperature of steel. In one of the author's tables in the section dealing with the elimination of sulphur, the sulphur was shown to be going out whilst the manganese was rising. The author attached great importance to the manganese; his pig-iron contained a large amount of this constituent, but Cleveland pig-iron was not such.

Mr. J. H. Whiteley, referring to the author's Table I, said he calculated the amount of lime required to form the tetra-phosphate and the base to form the monosilicate, and he had a very small excess of base. If one allowed 3CaO instead of 4CaO, the excess of base in the first line, instead of being $-0{\cdot}040$ would be $+0{\cdot}095$, and similarly all down the column in the table. The various figures given did not total to 100, but to 92 or 93, there being therefore about 7 per cent. not accounted for, and something was present to make up the 100 per cent, and perhaps that was thought to be alumina, but alumina acted as an acid, and would invalidate the author's figures. In the author's Table II results were given which had not been obtained hitherto, namely, a basic slag containing no ferrous oxide and this was, he (the speaker) thought, unique. He had never met with the occurrence before. Had the author, he asked, allowed in his analyses for the possibility of the presence of a higher percentage of oxide of manganese, Mn_3O_4 for example? Had the slag sample been taken at the surface, or well down? How did the author allow for the fall in phosphorus from 0·4 to 0·305? He (the speaker) thought an explanation was in the fact that the reduction of the ferric oxide had not been sufficiently rapid to allow of the oxidation of the phosphorus by the ferrous oxide formed.

Professor Turner said he was glad to agree largely

UNIVERSAL BAR COAL-CUTTER.

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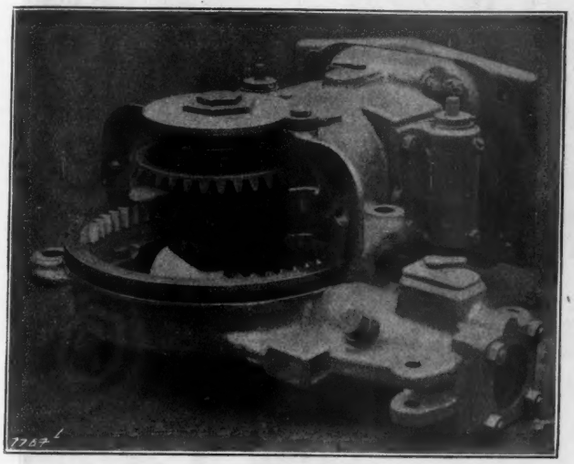


FIG. 5. GEAR HEAD WITH BACK COVER REMOVED.

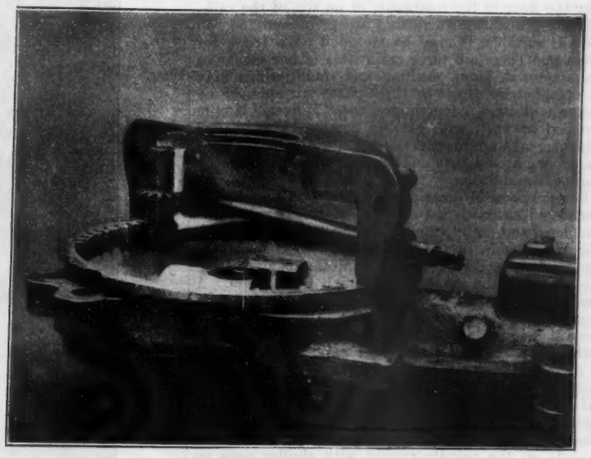


FIG. 6. SLEWING GEAR.

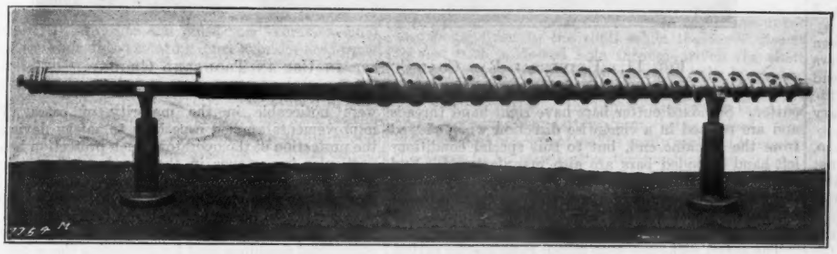


FIG. 7. MAVOR AND COULSON CUTTER BAR.

FIG. 8. FIG. 9.

FIG. 8. STAR CUTTER AND LOCKING PICK. FIG. 9. SINGLE PICK.

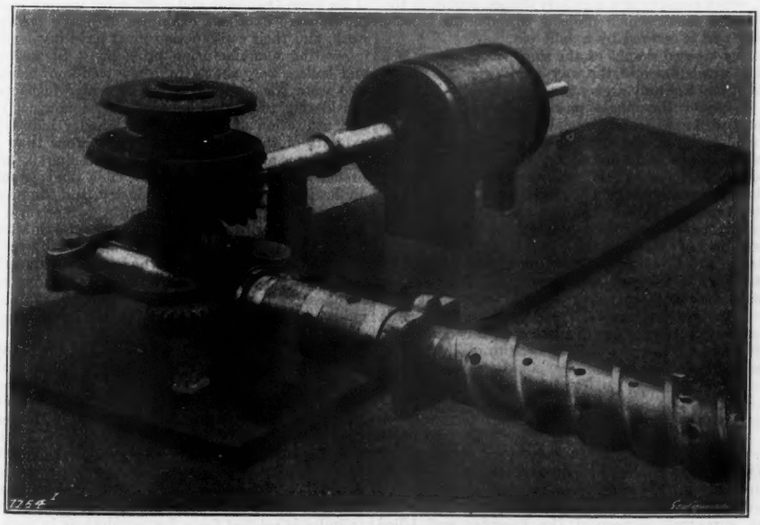


FIG. 10. COMPLETE DRIVE FROM MOTOR SHAFT TO THE CUTTER BAR.

with the author despite the criticism he could put forward on a number of questions of detail. He (the speaker) had collected a large number of slag specimens at the time when slag was considered solely from the mineral point of view. It had long been evident, however, that the slag had to be considered in a different aspect when fluid. He thought the author had devoted more time than was necessary to atomic calculations, and he (the speaker) considered the subject from the physical, rather than from the atomic, standpoint. The time of reaction between the metal and slag also came in. The author's conclusion to the effect that additions of "basic" oxides merely passed into solution and the type of compound had not altered, was a view which he (the speaker) expressed some twenty years ago.

The chairman asked the author to reply by writing to the discussion.

(To be continued.)

MAVOR AND COULSON COAL CUTTERS.

IN every field of industrial activity to-day there is the greatest necessity for a large reduction in the costs of production. Without such changes the economic recovery of the country or of any particular industry must be a slow and tedious process. In these endeavours one of the essential requirements is a cheap and abundant supply of fuel. The extended applications of machinery to the processes of coal winning is one of those developments which have for their aim the reduction of arduous and costly manual toil and is imperative if cheap fuel is to be obtained. Great progress has been made in this field by British engineers, and of them the Glasgow firm of Messrs. Mavor and Coulson, Limited, may be taken as the most outstanding. The machines manufactured by them have been applied in mines in all parts of the world, and their continuously increasing use is a criterion of the suitability of their design and construction for the exacting conditions under which they operate.

There are three distinct types of coal cutter, known as the bar, the chain and the disc machines. It is difficult to make any definite statement regarding the combination of conditions which favour the use of any one of the three types, but it may be said that the disc type cannot be applied under such a variety of conditions as the other two. The disc machine was for many years the favourite type, but the figures published by the Home Office show that the number of such machines has remained constant during the last seven years, while the other two types have found extended application. Compressed air and electricity either alternating or direct current, are used for the operation of all three types of machine.

The bar coal cutter manufactured by Messrs. Mavor and Coulson, Limited, of Glasgow, is given the name "Universal," because one factor to which it owes its popularity is its suitability for all varieties of work. In service it may be started on work at the shaft in driving roadways through the shaft pillar, followed by "shortwall" working to develop headings in order to open out space for its work on "longwall" faces or,

again, it may be applied with equal efficiency in what is termed "room and pillar" working.

The machine is mobile, the haulage gear serving the double purpose of feeding the machine while working and for flitting it from header to header. It is mounted on its own sledge and is hauled by its own power with the use of wire rope, at a speed of about 50 ft. per minute over the floor of the roadways, or on top of the rails. When the distances of flitting are great and the rail tract is suitable, it may be mounted on a truck for removal. There are three main sizes of bar machines manufactured, large, medium and small, which may be operated by direct or three-phase currents, or by compressed air. A fourth size, the "Midget," is only supplied to work with electric power. The general arrangement and construction of the details of a bar machine may be seen in the illustrations given on pages 614 and 615.

For purposes of description the coal cutter may be considered as consisting of three principal parts, the gear head and cutter, the motor and the haulage gear. The relationship of these parts may be seen in the general drawings, Figs. 1 and 2. Motion is given from the motor to the cutter bar through bevel gears. A bevel pinion is fitted on the end of the motor shaft and engages with the wheel above it, which is keyed on the large diameter of a long boss mitre wheel which rotates with it and drives the cutter bar pinion. The spindle of these wheels has an enlarged neck on which a screw thread is cut. This spindle with its wide flange is cut out of the solid from a steel forging. Its construction may be seen in the general drawing, Fig. 1, where it is depicted in its working position. The threads on the spindle engage with similar ones on the gear head and back cover. By screwing the spindle out a few threads the wheels may be raised until they are totally disengaged, leaving the rotor free to revolve without any connection with the cutter bar. Fig. 3 shows the position of the gear when disengaged.

The photographic view, Fig. 5, on page 615, taken of the gear head with the back cover removed, shows the gears in place. The lower part of the gear head is known as the "banjo" and carries the end of the cutter bar and the mechanism through which its rotary and reciprocating motions are imparted.

The rotary mechanism has already been referred to, but it must be noted that the cutter bar pinion is not keyed rigidly to the bar, but is held in position by two long keys in such a way as to permit the movement of the bar in the line of its axis. This arrangement is necessary to allow the reciprocating motion to be given to the bar at the same time as the drive from the pinion causes its rotation. The reciprocating motion is obtained from the worm cut on the extended boss of the pinion. Fig. 4, on page 614, shows how the motion is taken from the worm to the worm wheels to obtain the travel for the side rods connected to the thrust block. The worm wheels rotate on studs which are riveted to the base of the "banjo" and support pins, situated eccentrically on the top side of each, from which the reciprocating motion is obtained.

The cutter bar is slewed into and out of action by rotating the "banjo," as shown in Fig. 6. This is effected by turning a gear shaft which passes through the back cover of the gear head. On the gear shaft there is a worm wheel which carries a spur pinion on its spindle. The pinion meshes with the rack formed on the inside of the top face of the "banjo."

The slewing operation just referred to may be performed by the use of a hand ratchet on its square end or by a power drive through a chain from the haulage gear. There are snugs provided on the gear head and "banjo" so that the bar may be fixed in line of the axis of the machine for cutting headings or at right angles to it for cutting on a longwall face.

A distinctive feature of the "Universal" coal cutter is the facility with which the whole gear head can be raised relatively to its base by means of screw jacks. These also give facilities for elevating or depressing the point of the cutter bar when at either side of the machine and even while the machine is cutting. When cutting on an uneven floor or when ironstone or other obstructions are met with, or when cutting on a band the height of which from the floor varies, this provision is much appreciated. The jacks for the purpose are provided with ball and socket bases. Extension and contraction of the distance between the sockets is provided for by making one fixed to the sledge of the machine and mounting the other on a slide in guides.

The cutter bar, Fig. 7, is made of a special grade of nickel steel, which combines the properties of toughness and hardness. In form the standard bar is tapered towards its point and has a spiral thread upon it which is cut out of the solid. The thread is made of continuously varying pitch throughout its length and acts as a worm conveyor to carry the cuttings away. Sometimes cutter bars of parallel form or of modified taper are used to break up a band of dirt in a seam. Between the threads, tapered holes with feather ways are cut to receive the shanks of the picks while the end of the bar is drilled to receive the shank of the star or end cutter. Standard cutter bars have right-hand threads and are rotated in a clockwise direction when viewed from the machine end, but to suit special conditions left-hand threaded bars are also manufactured. End thrust in the cutter bar is taken by a double thrust ball bearing. The bar may be easily released for removal by taking out a set pin from its root end, to which access is obtained through a plug hole in the gear head.

The cutter picks are drop-forged from special carbon steel. The star cutter, shown in Fig. 8, on page 615, is mounted in a socket at the end of the bar and is held in position by a locking pick having a square neck, which engages in a similarly-shaped socket in the bar, and a shank which projects through the side of the bar and is secured by a split pin.

On the tapered shanks of the single picks there is a feather which fits into the way cut in any one of the holes in the bar and prevents the pick from turning. The shape of the single pick is shown in Fig. 9, on page 615. A general assembly view of the main gearing, given in Fig. 10, shows the complete drive from the motor armature to the gear head and on to the cutter bar.

The successful operation of the bar coal cutter is not confined to places where there is a level bottom already prepared, but is possible even in troubled ground. An example of this is depicted in Fig. 11, which shows a Mavor and Coulson machine cutting through at a fault. This photograph was taken in a Lanarkshire colliery. In the view shown the bar is working just below the uncuttable rock, the only work afterwards being the fixing of shots in the rock after it is under-cut. In this way the machine may be used to reach the coal through the fault.

(To be continued.)

MAVOR AND COULSON UNIVERSAL BAR COAL-CUTTER.

FIG. 11. UNIVERSAL BAR COAL-CUTTER IN USE IN TROUBLED GROUND.

THE LAUNDRY EXHIBITION.

MECHANICAL appliances enter so largely into the equipment of a modern laundry that it is perhaps not surprising that machinery represented by far the most important section of the Laundry and Allied Trades Exhibition which was held at the Royal Agricultural Hall, Islington, N., from the 9th to the 16th inst. The exhibition, which was promoted by the Society of Laundry Engineers and Allied Trades, Limited, is the second held since the termination of the war, and was certainly of a more extensive and representative character than the previous one held in November, 1920. The machinery exhibits were particularly numerous, and although most of them were of British manufacture, foreign-made machinery, particularly that of American origin, was more in evidence than was the case at the last exhibition.

The exhibits included many items of interest to engineers, and although there were no particularly striking innovations, improvements in detail design were noticeable in the majority of cases. These improvements applied especially to safety devices for the protection of the operators, such protection being of particular importance in the laundry industry where machinery is mainly controlled by women workers. Many of the washing machines, for instance, were fitted with devices to prevent them from being set in motion while the charging doors are open, and some of the centrifugal machines used for extracting the water from wet clothes were arranged so that the cover must be closed before the machine could be started, and could not be opened again until the basket had come to rest. Several of the large Decoudun and multi-roller ironing machines shown were excellent examples of heavy engineering work, and their construction must have involved some interesting manufacturing problems. Steam engines and boilers were shown by a few well-known firms, as also were some special types of boiler furnaces, but considering the importance of the economical raising and utilisation of steam to the laundry industry, the exhibits of this class were less numerous than might have been anticipated. Water softening is another branch of engineering work which finds numerous applications in the laundry industry, and the necessary plant for the purpose was shown by two or three firms. Most of the water-softening apparatus exhibited was of the type in which the water is softened by passing it through artificial zeolite, which is subsequently regenerated by the action of brine. By this process the hardness can be completely eliminated, and a very material economy can thus be effected in the use of soap and other washing materials.

From their obvious importance in the laundry it will be logical to deal first with the washing machines shown, but as nearly 20 firms each exhibit four or five different models of these machines it will be evident that we can only refer to a few of them. The common type of washing machine comprises a horizontal cylindrical vessel partially filled with washing solution which is heated by steam. Inside this cylinder, and co-axial with it, is a perforated cylinder, usually of brass, in which the clothes are placed, and this internal cylinder is rotated for a few revolutions in each direction alternately. Longitudinal perforated ridges are formed on the inner surface of the rotating cylinder to collect the washing solution and allow it to pour over the clothes and also to prevent the latter from collecting into a more or less impermeable mass. Messrs. Manlove, Alliott and Co., Limited, of Nottingham, showed several machines of this type, their latest design being represented by a "multi-jet" washer having a cylinder 36 in. in diameter by 72 in. long. This machine has quick-acting valves for filling, emptying and steam supply, and the main doors are fitted with small auxiliary doors which enable washing materials to be added while the machine is in operation. The inner cylinder is driven by gearing at both ends and runs in external ring-oiled bearings, the access of water, &c.,

to the latter being prevented by glands fitted in the ends of the external cylinder.

Included in the exhibit of Mr. James Ritchie, of Partick, Glasgow, is a new form of end for washing machine cylinders patented by Mr. W. J. Dunnachie. With this arrangement, steam and air enter through a trunnion at one end of the cylinder and are distributed by radial copper pipes, but a port formed in the trunnion is provided so that the steam and air flow only through those pipes which terminate below the level of the solution in the cylinder. It is claimed that the use of this device, which can be fitted to existing machines, results in a considerable saving of both washing materials and water, owing to the rapid and effective aeration of the latter. At this stand is shown a washing machine in which the internal cylinder is divided into 10 compartments by perforated diaphragm plates, so that batches of work can be kept separate. In most cases the external cylinder is of galvanised steel, and the internal one of brass or gunmetal, but Messrs. Smith and Paget, Limited, Crown Works, Keighley, showed a machine in which both cylinders were constructed entirely of wood, although they also exhibited a machine of metal construction as well as a small electrically-driven washing machine fitted with a mangle for domestic use.

At the stand of the American Laundry Machinery Company, Limited, whose London address is 36 and 38, Victoria-street, S.W., we noticed a large washing machine measuring 42 in. in diameter by 84 in. long, of which the cylinders were constructed of Monel metal, the strength and corrosion resisting properties of which appear to offer considerable advantages in this particular application, although its cost would probably be a drawback. Messrs. D. and J. Tullis, Limited, Sardinia House, Kingsway, W.C., also show a 21-in. by 36-in. machine constructed of the same material. An interesting feature of the washing machines shown by Messrs. I. Braithwaite and Sons, Ibis Works, Kendal, is that the ends of the rotating inner cylinder are formed by cast-iron spiders, the arms of which are arranged tangentially to a central ring so as to transmit the torsional stresses more effectively. The same firm show washing machine specially designed for use with benzine in the dry cleaning process, as well as a steam-heated still for purifying the benzine after use. Of the various special types of washing machines shown we have only space to mention those exhibited by Mr. G. W. Taylor, of Oldham, which are specially suitable for washing flannels. These machines comprise a rectangular open tank over which is mounted a shaft carrying two arms at right angles to its length. On the ends of the arms, beaters, in the form of inverted troughs, are mounted, so that when a semi-rotary motion is imparted to the shaft, the beaters rise and fall on the goods in the tank.

Of the ironing machines shown, the most interesting type is that known as the "Decoudun," in which the work is passed between a large padded roller and a curved steam-heated bed placed below the roller. Messrs. Manlove, Alliott and Co., Limited, show a machine of this type in which the roller is 120 in. long and 42 in. in diameter. In this machine, the roller can be lifted off the bed by means of a swinging arm connected at one end to the bearings of the roller and at the other end to a worm wheel driven through reduction gearing from the main shaft. The most interesting exhibit of this firm, however, is a new Decoudun-type machine, known as the "Vac" ironer, having a roller 120 in. long and 30 in. in diameter. The roller, which is covered with felt in the usual way, is fluted longitudinally and perforated with numerous holes drilled through the periphery at the bottoms of the flutes. A suction fan is connected to the roller through a hollow trunnion at one end, and by this means the vapour produced when damp linen is passed through the machine is drawn off as soon as it is formed. A steam coil is placed inside the roller to keep it warm, but the ironing action is due to the steam-heated bed. We understand that the finish of the work produced by the machine is not quite so good as that from an ordinary Decoudun ironer, but that its output is materially increased. A suction Decoudun, of Dutch manufacture, having a roller 160 in. long by 32 in. in diameter was shown at the stand of Messrs. Thorp, Medley and Co., Raven-street, Pendleton, Manchester, while Messrs. Thomas Bradford and Co., 141 and 142, High Holborn, W.C. 1, showed a machine in which air is supplied to the roller under pressure. The air passes over a nest of gilled steam pipes inside the roller, and, after being heated in this way, leaves through holes in the roller taking up the moisture from the work before it finally escapes. This firm, and several others, exhibit ordinary Decoudun machines of various sizes.

The large multi-roller ironing machines which are used for finishing flat work such as tablecloths, are similar in principle to the Decoudun ironers, but have from four to eight rollers of comparatively small diameter working in steam-heated beds and operated in series. Those of Messrs. D. and J. Tullis, Limited, are designed on the unit principle, so that the user commencing with a four-roller machine can subsequently add another four-roller unit and afterwards, if necessary, a separate unit with a large steam-heated drying cylinder. The additional rollers and drying cylinder unit, of course, greatly increase the capacity of the machine. In these machines the rollers are mounted on spring bearings and the pressure can be adjusted to suit any class of work. Messrs. Aublet, Harry and Co., Limited, 53–55, Curtain-road, E.C., showed a six-roller machine of this type provided with simple means to enable either direct pressure or spring pressure to be applied to the bearings at will. In another type of ironing machine used in laundries. the work is placed on a flat reciprocating table and passed under one or more gas-heated rollers, and several examples of these machines were shown as well as of clothes presses in which the garment is pressed between two steam-heated and padded platens, through perforations in which the steam passes into the fabric.

Hydro-extractors, as the centrifugal drying machines used in laundry work are called, were shown by about a dozen different firms, one of the most interesting machines of this type being exhibited by the American Laundry Machinery Company, Limited. In this machine, the basket is driven directly by an overhead vertical-shaft motor, and the latter is automatically started by the act of closing the cover. A time switch is also provided to stop the motor and apply the brake after a predetermined interval has elapsed, and, when the basket has come to rest, the cover is raised automatically and a lamp lighted to indicate to the attendant that the work is finished. One of the machines shown by Messrs. Manlove, Alliott and Co., Limited, was fitted with a centrifugal locking device to prevent the wire cover of the basket from being raised until after the machine had come to rest. In this machine, the spindle, which extends slightly above the cover, is fitted with two discs, one above the other, the upper disc being fixed to the shaft while the lower disc is formed with a slotted hole through which the shaft passes. When the machine is running, the lower disc flies out by centrifugal force so that part of it rotates just above the edge of the central aperture in the cover and prevents the latter from being raised. The movable disc can, of course, be easily replaced to enable the cover to be raised after the machine has stopped. Messrs. Watson, Laidlaw and Co., Limited, 98, Dundas-street, Glasgow, showed a 27-in. machine arranged so that the cover must be closed before the starting lever can be moved into the "on" position, and, when the machine is running, a lock controlled by a cam mounted on the vertical shaft prevents the cover from being raised. The same firm also showed a 36-in. electrically-driven hydro extractor in which the basket, although constructed of steel, was completely encased with vulcanite. The machine would therefore be suitable for the class of work in which the use of corrosive solutions is necessary.

The continuous drying plant shown by Messrs. W. W. Wardle and Sons, 79, Queen's-road, Finsbury Park, N. 4, was described in connection with the last exhibition on page 706 of our 110th volume, and drying plant was also exhibited by Messrs. T. Bradford and Co., while Messrs. Matthews and Yates, Limited, Cyclone Works, Swinton, Manchester, displayed fans for use in connection with this class of work. As previously mentioned, the water-softening plant exhibited was for the most part of the type employing artificial zeolite, and apparatus of this class was shown by Messrs. United Water Softeners, Limited, Imperial House, Kingsway, W.C. 2, who are the patentees of the well-known "Permutit" process. Messrs. William Boby and Son, Salisbury House, London Wall, E.C. 2, showed a plant, known as the "Azed" water softener, capable of reducing 14,000 gallons of water from 10 deg. hardness to zero hardness in the period of 10 hours between regeneration. The latter operation takes about 1 hour, and the total amount of water used for the purpose is about 5 per cent. of the quantity softened. Messrs. John Thompson, Limited, of Wolverhampton, showed a plant of the same type, as well as a Kennicott softener capable of treating 1,000 gallons per hour.

Steam engines and boilers were shown by Messrs. E. S. Hindley and Sons, 11, Queen Victoria-street, E.C., Messrs. Robey and Co., Limited, Lincoln, and Messrs. Davey, Paxman and Co., Limited, Colchester, the last-mentioned firm having a plant in operation for supplying steam and power for use in the exhibition. The products of these firms, however, are too well known to engineers to need description. Forced-draught boiler furnaces were shown by the Turbine Furnace Company, Limited, 238B, Gray's Inn-road, W.C. 1, and by Messrs. Meldrums, Limited, Timperley, Altrincham, the latter firm also exhibiting an oil-fuel burner fitted with a fine regulation dial to enable the supply of oil and steam to be set for any predetermined conditions of working. Messrs. J. Thompson, Limited, in addition to the exhibits previously mentioned, showed a model of one of their Lancashire type boilers with dished ends and corrugated flues, a vertical cross-tube boiler and sectional-type superheaters. Messrs. Lancaster and Tonge, Limited, Pendleton, Manchester, also had a stand at which their well-known steam traps, metallic packings and piston rings were displayed.

The only internal-combustion engine in the exhibition was a cold-starting semi-Diesel crude-oil engine shown by Messrs. Bates and Scholes, Limited, Victoria Works, Denton, Lancashire, who make these engines with capacities up to 100 b.h.p.

"THE ABOLITION OF EUCLID."

TO THE EDITOR OF ENGINEERING.

SIR,—There are many who deplore the banishment of Euclid—and still more the methods by which that banishment has been effected—from the curriculum of the engineering schools, referred to in your issue of May 11. The controversy as to the utility of Euclid was bound up with that of compulsory Greek; and it is difficult to avoid a suspicion that Euclid was deliberately sacrificed in the hope of saving Greek. But in any case, the controversy was confined to circles and schools which had, and have little or no, connection, and certainly no sympathy, with engineering; and it is a matter for regret that those who know and appreciate the importance of orderly thought and commonsense reasoning did not prevent the abolition of Euclid in the engineering schools.

It is significant that the two outstanding "faults" found with Euclid by those who desired its abolition were:—(1) that it does not reach finality on the question as to whether parallel straight lines will or will not meet at infinity; and (2) that it is confined to a space having only three dimensions.

In place of Euclid, engineering students are now required to consider seriously such things as "imaginary conics," and "functions" which "remain beautiful in spite of the fact that they are capable of practical application"; while such facts as that any two sides of a triangle are together greater than the third are apparently not even mentioned to them.

During the controversy it was stated by those who sought to abolish Euclid that their desire was only to make Euclid optional instead of compulsory, and to ensure the most efficient treatment of Euclid by so arranging that his results, with their practical applications, might be studied more fully by those concerned with them. This, of course, was plausible, and disarmed criticism; for there was undoubtedly much time wasted in the treatment of purposeless corollaries and "riders." But in fact, the result is (as doubtless was intended) that, Euclid has been totally abolished in all schools; and the consequent loss to engineers is both obvious and real.

Yours faithfully,

May 14, 1923. ERNEST G. BECK.

TO THE EDITOR OF ENGINEERING.

SIR,—Permit one whose main occupation since 1900 has been the teaching of mathematics to young engineers and science students to thank you for your wise leader on "The Abolition of Euclid," on page 590 of your last issue. My regret is that the evil has now gone on so long that it is difficult to believe that it will ever be remedied. As you suggest, the change has come about to suit the wishes of the teachers who found "Euclid" a very difficult subject to teach. A teacher had to be a very good one indeed to make the great majority of a class of ordinary boys understand their Euclidean Geometry. Now the vast majority of teachers are not very good indeed. Quite a large proportion are often rather poor, and the effect on the students of being taught Euclid by an incompetent master, it was easy to argue, must be much more disastrous than the same gentleman's efforts to teach other things. Your suggestion that learning props. off by heart was good training for the memory at all events, would be shouted at by all "true educationalists" who are agreed that to teach children things to remember is vicious. The late Professor John Perry was a great exponent of the view that no child should be taught anything it did not like, and that all idea of education as a discipline to be undergone should be banished.

The results of this laxity are much as you describe them. For several years I took part in various public examinations and I found that among young engineers there was growing up a generation which not only did not know Euclid's proofs, but did not even know what constituted a "proof," if asked to prove that the sum of the angles of a triangle was equal to two right angles whole classes, one after another, would sketch a set-square and write down "45 deg. + 90 deg. + 45 deg. = 180 deg.," the only break in the monotony being when the tune was changed to "30 deg. + 60 deg. + 90 deg. = 180 deg.," or when some more energetic candidate wrote down both.

Yours, &c.,

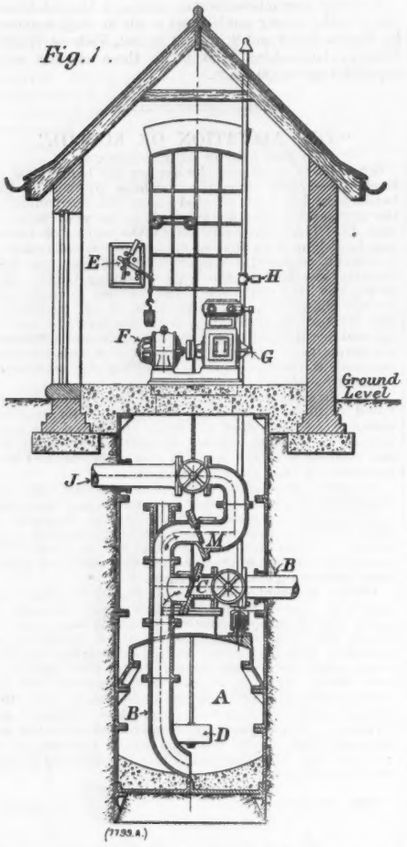
"THIRTY YEARS A TEACHER."

BRITISH IRON AND STEEL PRODUCTION.—The National Federation of Iron and Steel Manufacturers state that the production of pig-iron in April amounted to 552,200 tons, compared with 633,000 tons in March and 394,300 tons in April, 1922. The furnaces in blast at the end of the month numbered 216, an increase of 14 during the month. The output of steel ingots and castings in April amounted to 749,400 tons, compared with 802,500 tons in March and 404,200 tons in April, 1922.

AUTOMATIC PNEUMATIC SEWAGE EJECTORS.

CONSTRUCTED BY MESSRS. DANIEL ADAMSON AND CO., LIMITED, ENGINEERS, DUKINFIELD.

Fig. 1.



(7733 A.)

Fig. 2. SECTION THRO AA

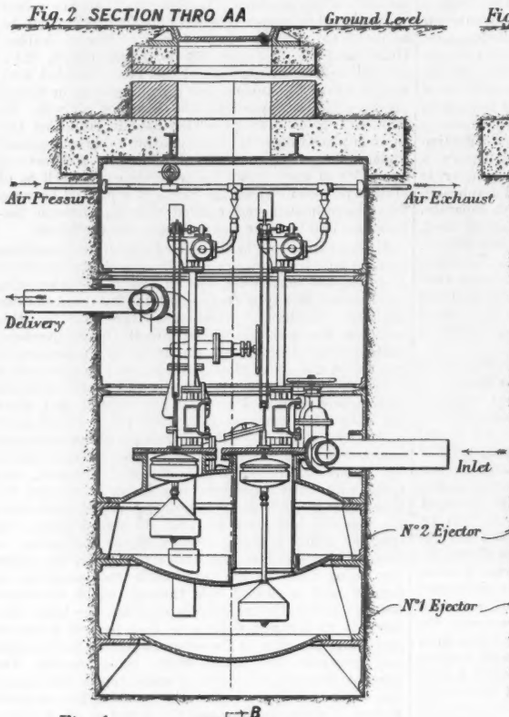


Fig. 3. PART SECTION THRO BB

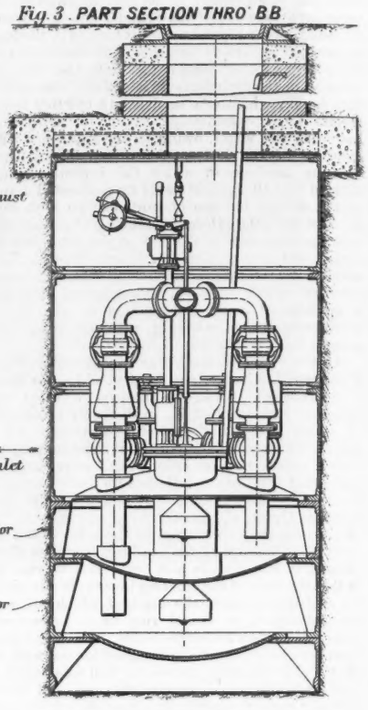
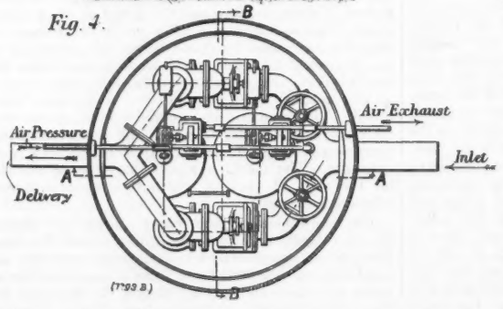


Fig. 4.



(7733 B.)

THE removal of sewage from inhabited areas presenting no favourable features as regards fall, has for many years been accomplished by the means of pumping or ejector stations. In the latter a supply of compressed air has usually to be piped to the station and stored. A new type of ejector station has recently been designed by Messrs. Daniel Adamson and Co., Limited, Dukinfield, Manchester, embodying several interesting characteristics. Messrs. Adamson's new ejector is illustrated in Fig. 1 herewith, while Figs. 2, 3 and 4 show an installation embodying a pair of ejectors working together. The first installation is shown operated by a small motor compressor unit, while the second is arranged to be supplied with air from a more remote source or central station. In both cases the level of the sewage is utilised to cut the air pressure in or out. In the first case this is done by a float operating a switch starting the motor; in the second it is accomplished by a valve on the air pipe, operated direct by the floats.

In Fig. 1 the sewage flows from the inlet pipe B, into the body of the ejector A, by gravity past the flap valve C. As the level of the incoming sewage rises the float D is raised and the motor F is cut in by means of the float-operated switch E. The air delivered by the compressor G, passes into the ejector body and forces the sewage out past the flap valve M, through the pipe J. As the float falls the motor is cut out and the ejector body is opened to exhaust, when, on the pressure being relieved, a fresh supply of sewage enters through B. The communication to atmosphere is effected automatically by means of the magnetic valve H which is maintained closed so long as the motor is working, but opens as soon as it is shut down, the valve being worked by the float opening and closing a solenoid circuit.

This cycle will repeat itself so long as there is sewage to flow into the body of the ejector. The volume and pressure of air are directly proportional to the work to be done in forcing the sewage into the main J. The head is comparatively small and a low-pressure type of compressor suffices, and as this works only intermittently it keeps sufficiently cool without circulating water. If it be considered preferable to run the motor continuously, the gear is arranged so that the load can be thrown off automatically when the ejector is filling, or again the motor can be arranged to work intermittently when the flow is small and continuously when it rises above a predetermined amount. The air compressing plant may be at a distance from the ejector, and can therefore be removed from all risk of flooding. The only moving parts above ground are the usual inlet and outlet back-pressure valves, and the float gear. These can be readily inspected. The system avoids the use of a receiver and compression to a high pressure, with all its attendant losses by leakage, &c. This, again, results in some saving in capital expenditure, directly due to the omission of the receiver itself, and indirectly to the decreased space occupied, reduced amount of excavation, &c.

The apparatus is only under pressure and under load when actually pumping, so that the power consumed is directly proportional to the work done in lifting the sewage. In the arrangement shown in Fig. 1 the whole ejector is accommodated within cast-iron tubing, the lower portion of which forms the body of the ejector itself. The top of the body is formed by a dome cover. The inlet and discharge to the ejector body takes place through one pipe. Figs. 2 to 4 show a tandem arrangement with float-operated valves admitting compressed air from a piped supply. The ejector bodies are placed one above the other, the bottom of the upper forming the cover of the lower one. The manner in which the inlet and outlet mains are branched to the two ejectors is shown in Figs. 3 and 4. This arrangement ensures a continuous discharge.

With the Adamson arrangement of ejector as pointed out there is no storage of air and leakage; when idle the plant is open to the atmosphere; air pressure is not built up and then expanded down to the atmosphere again; the motor starts up without load on the compressor piston; in twin installations, by reason of the valve arrangement, only one ejector can operate at a time, since when one is being charged with air the other is open to the exhaust; no excessive air pressure is possible, because directly the air overcomes the sewage pressure the ejector begins to discharge. The Adamson apparatus operates about once every 5 minutes, compared with the once per minute which is common practice in previous systems. In a year's working this means a reduction of over 21,000,000 operations with consequent reduction in wear and tear of the moving parts. In addition, account should be taken of the slip due to clearance volume which is greatly reduced as a result of the decrease in operations. This represents a considerable saving in power.

An order for similar plant has been received by Messrs. Adamson from the High Commissioner of the Union of South Africa.

WOODWORKING MACHINERY FOR SURFACING AND THICKNESSING.

ONE of the most serviceable tools in a woodworking shop is a machine suitable for surface planing work and for planing material to definite thicknesses. A machine of that type manufactured by Messrs. Wadkin and Co., of North Evington, Leicester, is illustrated on the opposite page by three general views and three drawings. Figs. 1 and 2 show the back and front views respectively of the standard machine, while Figs. 3 to 6 show elevation, section plan, and a general view of the machine fitted with a tilting surface table for taper planing.

The main frame is a heavy casting with a base area large enough to prevent vibration, but shaped to provide ample foot room at the front for the operator. On the main frame are mounted four triangular brackets, two at the front and two at the back, on the inclined edges of which the surface tables are supported. The horizontal edges are bolted to the main frame through slots to permit setting in any desired position and to allow the tables to be drawn apart. The possibility of drawing out the tables is of great convenience when changing and sharpening the cutters. The freedom of adjustment of the tables on the inclined

WOOD-WORKING MACHINERY FOR SURFACING AND THICKNESSING.

CONSTRUCTED BY MESSRS. WADKIN AND CO., ENGINEERS, LEICESTER.

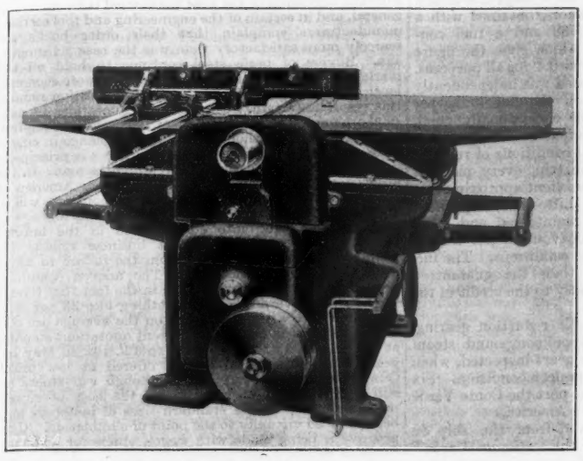


FIG. 1.

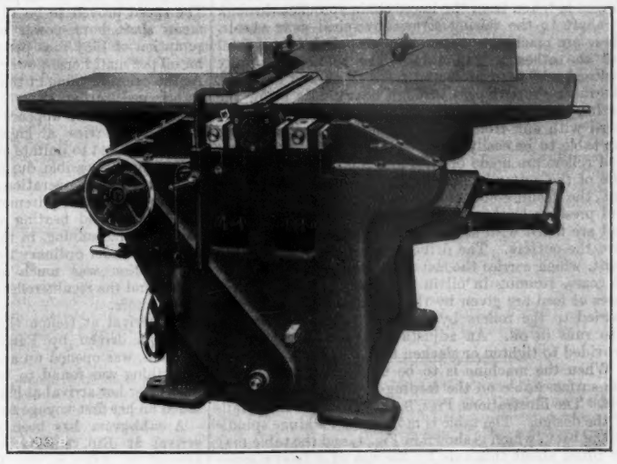


FIG. 2.

Fig. 3.

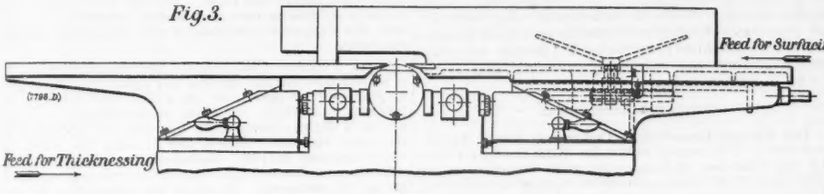


Fig. 4.

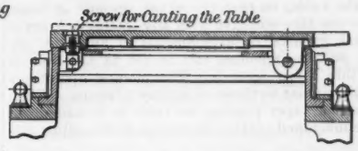
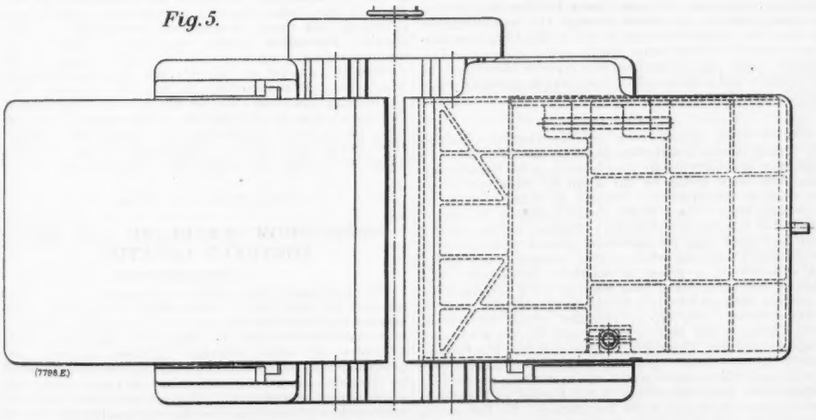


Fig. 5.



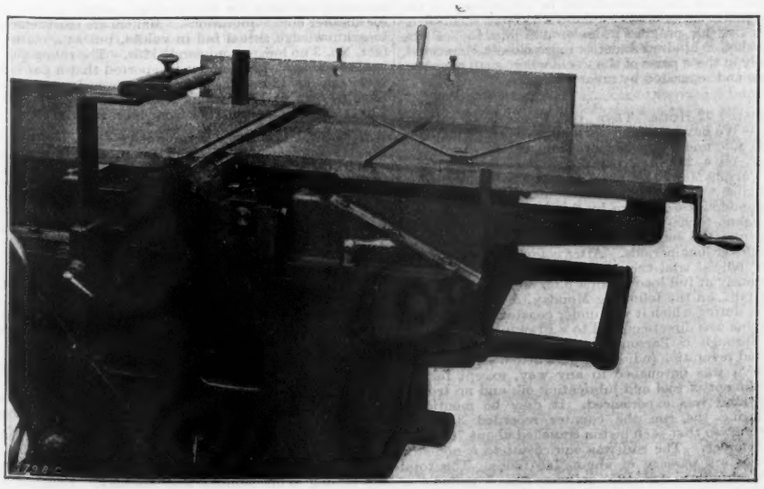


FIG. 6.

faces of the brackets is useful in permitting a rising and falling motion of ¾ in. for the tables. The total length of surface tables is 6 ft. 1 in. Each half is provided with steel lips at the edges to ensure freedom from chipping and to give the minimum gap over the cutters. The cutter block is driven by belt by means of the small pulley on its end, the fast and loose pulley and the striker gear seen in Fig. 1. The handwheel at the side controls the speed of the feed rollers beside the cutter block, when thicknessing operations are being performed. At the back of the surface table there is a fence supported from a bracket on the table and provided with the means of adjustment to position on the table so that it may be set at any angle to the surface of the table up to 45 deg.

The cutter block is of the two-knife circular safety type and revolves at 4,000 r.p.m. in heavy ball bearings enclosed in dustproof housings. The diameter of the cutting circle is 5 in., which is very large for a machine of the type, but gives a good cutting angle and a high peripheral cutting speed. It has been designed to conform with the new regulations under the Factory Act, which come into force at the beginning of next year. It is made from a steel forging, and the cutters are held in position by plates and secured by studs and nuts. For convenience in setting, two pairs of springs are fitted to each cutter. One pair raises the locking plate to allow the other pair to push the cutter out against the setting device. To set the cutters, one half of the surface table is drawn away from the normal position to permit of access to the cutter block, and the insertion of the setting gauge. This consists of two curved arms held apart by a spacing arm. When the gauge is laid on the back surfacing table the extreme tips of the projecting arms of the gauge are brought in contact with the cutter block to give the exact diameter of the cutting circle. The springs automatically press up the locking plate and press the cutter out against the setting edges. The bolts are then tightened and the same operation is performed for the other blade. If required, three and four-bladed cutter blocks are supplied, but the standard two-bladed type has the advantage that moulding cutters can be mounted on the block without upsetting the setting of the planing cutters. In the front view of the machine, Fig. 2, a telescopic guard of the bridge type is shown. It covers the whole of the cutter gap in compliance with the regulations under Section 79 of the Factory and Workshop Act introduced on January 1, 1923. The telescopic guard is balanced to prevent it accidentally falling on the cutters and may be locked in any desired vertical position.

The under-table used for thicknessing work is of considerable strength and is provided with two adjustable anti-friction rollers let into its surface in addition to

which carrier rollers are fitted at each end for supporting long work. The table is mounted on broad slides on each side of the main frame and may be raised and lowered 9 in. This is effected by the use of the hand wheel shown in the front of the machine, Fig. 2, from which motion is given to a chain within the casing. Motion is taken from the lower chain sprocket through its shaft to the raising screws by spiral gear wheels. These are machine-cut, one in each pair being of steel and the other of gun-metal. The gears are totally enclosed and thus protected from chips and sawdust. The raising screws pass through heavy nuts below the casting of the table. They are protected from dust and fitted with anti-friction ball thrust washers to enable the table to be easily raised and lowered. The power feed rollers are made of steel and are situated on each side of the cutter block, the feeding-in one is grooved but the feeding-out one is plain. The feed rollers and pressure bars are controlled by adjustable springs and are fitted with stops to prevent them being lifted into the cutters. The drive to the rollers is from the shaft, which carries the fast and loose pulleys, to a set of gears, running in oil in an enclosing case. Three rates of feed are given by the gears, and the motion is carried to the rollers by a heavy roller chain which also runs in oil. An adjustable chain idler wheel is provided to tighten or slacken the chain.

When the machine is to be used for taper planing the surface table on the feeding-in side is arranged to tilt. The illustrations, Figs. 3, 4 and 5, show the details of the design. The table is mounted on a hinge spindle at the back, which is shown in Fig. 4, and the table may be tilted about this axis by the use of a heavy screw at the front edge. The double-armed spanner shown, by broken lines, on this screw in Fig. 3, is the standard tool used for tightening up the cutter block. The amount of the rise is indicated on a scale on the front edge of the table, so that the exact amount of taper which the machine will give with any setting is known. No special fixtures or attachments of any sort are required, and the machine can be set to any desired taper within a few seconds. The planing operations are exactly similar to those of surface planing. When not in use for taper planing the table is locked down on to the machined surface by means of the adjustable screw.

When such a machine is installed in a pattern shop a great saving of time may be effected, as it is possible to obtain the necessary "draft" straight from the machine. A variety of work is possible with this machine, such as rebating, bevelling, mitreing, shaping newels of either the parallel or tapered type, and panel raising.

TRIALS AND MAIDEN VOYAGE OF SS. "CONTE VERDE."

THE turbine-driven Atlantic liner "Conte Verde," recently built for the Lloyd Sabaudo Company, of Genoa, by Messrs. William Beardmore and Co., Limited, of Dalmuir, was submitted in April to her measured mile trials followed by fuel consumption tests in the Irish Channel and in a trip to Genoa. This vessel is a sister ship to the SS. "Conte Rosso," constructed by the same firm, of which a full description of design and equipment appeared in ENGINEERING, vol. cxii, pages 198 and 223.

A series of progressive trials with a displacement of 16,930 tons were carried out on the Clyde measured mile on April 3 and 4. The results proved highly satisfactory, and a maximum speed of 20·15 knots was recorded, with the turbines giving 20,125 s.h.p. From the observations made in the tests, with the vessel running in both directions on the measured mile, the averages have been taken and are given in the table below, along with others obtained with a displacement of 19,000 tons :—

Date.	Displacement.	R.P.M.	S.H.P.	Speed.
	tons.			knots.
3–4–23	16,930	53·4	3,266	12·27
3–4–23	16,930	62·0	5,193	14·05
3–4–23	16,930	71·9	8,388	15·92
3–4–23	16,930	84·7	14,305	18·34
3–4–23	16,930	93·5	19,952	20·08
4–4–23	16,834	85·6	14,757	18·71
4–4–23	16,834	94·0	20,125	20·15
6–4–23	19,000	80·7	15,929	18·66
9–4–23	19,000	88·2	16,663	19·04

A 24-hour fuel consumption test was carried out in the Irish Channel, on April 8 and 9. In this trial the average revolutions over the whole period were 86·53 and 86·67 for the port and starboard propellers respectively, and the mean power developed was 15,925 s.h.p. The fuel consumption amounted to 156 tons in the 24 hours, which gives a result of 0·914 lb. per shaft horse-power hour.

After these fuel tests the Conte Verde was taken back to the Tail of the Bank, and, after taking aboard sufficient fuel to bring the total up to the full complement, she left on April 10 for Genoa, with a company aboard including Lord Invernairn, Mr. Douglas Vickers and the Marquis de la Penne. In this run of 2,222 miles the results proved again highly satisfactory, and the journey was accomplished in 4 days 23 hours. The speed proved to be 18·67 knots, obtained with a mean shaft horse-power of 16,068 and a fuel consumption of 155¼ tons per day, which gives the figure for oil per shaft horse-power hour as 0·9 for all purposes. As the calorific value of the oil used was independently ascertained to be 18,600 British thermal units per pound, the result appears to be exceptionally good. The ship carries a large equipment of auxiliary machinery, and to imitate normal conditions of running as nearly as possible during the trip, every piece of plant was kept in operation to an extent approximating to the normal requirements. Lifts were operated, the lighting and heating were maintained and other services kept running, in the endeavour to give a complete test under ordinary running conditions. The fuel consumption was much lower than the guaranteed figure, and the results reflect greatly to the credit of the constructors.

On arrival at Genoa the double reduction gearing, which is driven by Parsons type compound steam turbines, was opened up and the gears inspected, when everything was found to be in perfect condition. Six days after her arrival at her home port the Conte Verde sailed on her first voyage to South America.

A cablegram has been received from the ship on arrival at Rio, stating that the "Conte Verde" arrived at 2.0 p.m. on Wednesday, the 2nd May, having maintained an average speed of 19·26 knots, with a fuel consumption of 163 tons per day, which works out at 0·89 lb. of fuel oil per s.h.p./hour for all purposes. The ship subsequently arrived at Buenos Ayres; the machinery, including the double reduction helical gearing, was thoroughly examined and found to be in perfect order.

THE BRITISH CHAMBER OF COMMERCE, PARIS (INCORPORATED).—The annual report for 1922, recently issued by this Chamber of Commerce, gives evidence of the great activity which it continues to display in facilitating business intercourse between Great Britain and France and her Colonies. A glance through the report suffices to show the numerous ways in which the Chamber aids every branch of the home trade and commerce. The annual report also centralises the reports issued by the committees and corresponding members in several French and Colonial towns and districts.

THE JUNIOR INSTITUTION OF ENGINEERS.—During the dinner of this Institution, held on the 10th inst., to celebrate the thirty-ninth anniversary of its foundation, references were made by Sir John E. Thornycroft to the work of the president, Captain H. Riall Sankey, in improving the economy of the steam engine by the introduction of the entropy diagram; Captain Sankey stated that he hoped that further development and economy would result from the trials soon to be carried out under the direction of a group of scientific institutions, the tests of various types of heat engines being arranged for in no less than six panels. Whilst proposing the toast of "The Guests," Mr. W. J. Tennant could not refrain from adding to the history of Captain Sankey's entropy diagram and the Theta-Phi diagram of Mr. Macfarlane Gray; he also dwelt upon the progress in naval architecture and the comfort which the travelling public had experienced from the efforts of Sir Fortescue Flannery, the president designate of the Institution. Sir Fortescue, in replying, said that there should be no jealousy in the realms of science nor amongst those who band themselves together for its progress; he would like to see the membership of kindred societies more closely connected, especially in those parts of the world where such members were few and separated by great distances.

OFFICIAL 72-HOUR TEST OF PARSONS PARAFFIN MOTOR.—We have received particulars of an official test, carried out under the supervision of an Admiralty overseer, on a 28-b.h.p. paraffin engine, manufactured by the Parsons Motor Company, Limited, of Southampton. The engine was of the standard marine type, having four cylinders, 4·5-in. bore by 6-in. stroke, and running at 850 r.p.m. to 900 r.p.m. The object of the test was to demonstrate the suitability of the engine for full-power working over long periods. After completion of its usual 4-hours' official trial the engine was re-started and run continuously at full load, from 4 p.m. on Friday, May 11, until 4 p.m. on the following Monday, a total period of 72 hours during which it was under constant observation. The engine was direct-coupled to a Froude dynamometer brake through a Parsons metal-to-metal clutch, and speed and revolution indicators were fitted. Throughout the test it was untouched in any way, except for the replenishment of fuel and lubricating oil, and no trouble of any kind was experienced. It may be mentioned that during the run the counter recorded 3,621,000 revolutions, so that each piston travelled about 700 miles in its cylinder. The run was equivalent to a non-stop full-power sea passage of about 720 miles. The total fuel consumption was 195 gallons, and 7 gallons of lubricating oil were used. Full data were obtained during the test, which, when collated, we hope to publish in some detail at a later date.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Though in one or two departments conditions show a marked improvement as compared with the beginning of the year the revival is by no means general, and in certain of the engineering and tool sections manufacturers complain that their order books are scarcely more satisfactory than was the case six months ago. Buyers of basic steel continue to hold off the market in the hope of reducing prices to a more economic level, but the effect of the Continental position renders this result uncertain. On the week quotations of mild steel are unaltered despite the fact that coke and pig-iron are a little easier without reflecting any change in official rates. Activity at the basic steel furnaces is principally due to orders booked two to three months ago. In the absence of serious competition either from America or the Continent it seems unlikely that new contracts will be arranged on a lower basis. A considerable tonnage of acid steel is going into consumption in the finished sections, but here also current business reflects the feeling of uncertainty arising from the failure to arrive at a settlement in the Ruhr. The uneven conditions prevailing are strikingly reflected in the fact that though steel billets have advanced something like 33 per cent. compared with a year ago, bars on the average are only 5*s.* per ton dearer, the official current quotations standing at 12*l.* 10*s.* to 13*l.*, against 12*l.* to 12*l.* 10*s.* in May last year. Belgian material is still offered at low prices. One satisfactory feature is that though war stocks are still being offered at rates below the cost of current production, supplies of standard sizes of materials have been reduced virtually to the point of elimination. Good progress is being made with wagon orders for home and Colonial railways and colliery companies. Axles, wheel and tyre plants are better placed than at any period during the last six months, and there is a fair call for colliery machinery and tools. Activity in the armament shops is increasing now that orders are being received from the shipyards in connection with the recent warship contracts.

South Yorkshire Coal Trade.—The continued strength of export business has checked any tendency on the part of producers to offer more attractive rates for forward business. Deliveries on home manufacturing account are on a slightly lower level, but with the exception of necessary reserves collieries are clearing the whole of their increased output. Railway companies are taking sufficient supplies to augment reserves and meet increased traffic requirements. There is no diminution in the demand for coking slacks. By-product plants are operating full time. House coal reflects the seasonal change. Secondary grades are being absorbed for manufacturing purposes. Quotations :—Best branch handpicked, 32*s.* 6*d.* to 34*s.* 6*d.*; Barnsley best Silkstone, 28*s.* to 30*s.*; Derbyshire best brights, 25*s.* 6*d.* to 27*s.* 6*d.*; Derbyshire best house, 23*s.* to 24*s.* 6*d.*; Derbyshire best large nuts, 20*s.* 6*d.* to 22*s.* 6*d.*; Derbyshire best small nuts, 18*s.* to 21*s.*; Yorkshire hards, 22*s.* to 24*s.*; Derbyshire hards, 21*s.* to 24*s.*; rough slacks, 12*s.* to 14*s.*; nutty slacks, 10*s.* 6*d.* to 12*s.* 6*d.*; smalls, 7*s.* to 9*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Business in Cleveland pig-iron is very quiet. Production now quite meets current requirements, but there are practically no stocks, and little improvement in demand is needed to create a return of acute shortage. Makers, however, are gradually working off orders and are a good deal disturbed by the lack of new business to take the place of contracts approaching completion. Buyers are very backward and markedly disinclined to place orders beyond what is necessary to them for early requirements, as they look for another cut in quotations. Makers are most reluctant to acknowledge actual fall in values, but as a matter of fact, No. 3 no longer commands 125*s.* The ruling quality is obtainable at 124*s.*, and it is reported that a parcel has been sold at 123*s.* 6*d.* No. 1 is extremely scarce, and remains firm at 130*s.*; but No. 4 foundry is on sale at 120*s.*; and No. 4 forge runs from 115*s.* to 117*s.* 6*d.*

Hematite.—Continued comparative cheapness of East Coast hematite is resulting in a few sales to customers who usually consume Cleveland pig-iron, but supplies are becoming rather more plentiful, and values tend slightly easier. The recognised market quotation for Nos. 1, 2 and 3, is still 122*s.* 6*d.*, but parcels are being very freely offered at that figure. No. 1 hematite is 123*s.* 6*d.*

Foreign Ore.—Sales of imported ore are not heard of. Consumers have good stocks, and have heavy deliveries to come forward against contracts made so that they are off the market, and are not to be tempted by offers at low figures. Sellers are pressing parcels on the market, and best rubio is no more than 24*s.* 6*d.* c.i.f. Tees.

Blast-Furnace Coke.—Durham blast-furnace coke is as scarce as ever and consumers are experiencing difficulty in securing essential supplies. Local regular customers have to pay up to 45*s.* delivered for renewal of contracts.

Manufactured Iron and Steel.—Inquiry for finished iron and steel is small, but manufacturers are still fairly well off for work and adhere to recent quotations. Works are closing Whit Monday and Tuesday. Common iron bars are 12*l.*; iron rivets, 14*l.*; packing (parallel), 8*l.* 10*s.*; packing (tapered), 11*l.* 10*s.*; steel boiler plates 14*l.*; steel ship, bridge and tank plates, 10*l.* 10*s.*; steel

angles, 10*l.*; steel joists, 10*l.*; heavy steel rails, 10*l.* 10*s.*; fish plates, 14*l.* 10*s.*; black sheets, 14*l.* 10*s.*; and galvanised corrugated sheets (24-in. gauge, in bundles), 19*l.* to 19*l.* 5*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

The Trade Position.—Throughout the country the general trade position is not very encouraging at the present moment, and there are few who can see any sign of improvement in the near future. All over there is an absence of demand and the unsettled state of the markets of the world is causing buyers to operate with the greatest caution. The result is that dealings are of the hand-to-mouth description and for immediate requirements only. Inquiries do not give any indication of a buying movement coming along, and so the outlook all round is far from bright.

Scottish Steel Trade.—In the Scottish steel trade the conditions have changed but little and there is not much promise of an early betterment. The day-to-day demand is far from heavy and will not have much effect in staving off the day when orders now on hand get worked off. At the moment plant is being kept running fairly steadily, but the output is far ahead of the rate at which new business is being secured, and although there is a fair tonnage still on the books, most of that will be cleared off in a month or two. Ship plates are extremely dull, but the turnover in sectional material is fairly good. Home consumers of black sheets are not requisitioning to any extent, but some fair lines are going through on export account. The general export trade is very poor at the present time, which may to some extent be due to the high level of prices. The latter are very firm, and for home delivery are as follow:—Boiler plates, 13*l.* per ton; ship plates, 10*l.* 5*s.* per ton; sections, 10*l.* per ton; and sheets, 12*l.* 10*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—There is not a great amount of work passing in the West of Scotland malleable iron trade, and unless there is a considerable improvement in the demand the outlook will soon be serious. Every endeavour is being made to secure new business, but there is little on offer. In the steel re-rolling branch conditions continue quite good. Prices are without change at 12*l.* 10*s.* per ton for "Crown" bars, delivered Glasgow.

Scottish Pig-Iron Trade.—A dull tone prevails in the Scottish pig-iron trade and the demand is somewhat weaker. Inquiries for fresh lots have also fallen off considerably, and this is very noticeable with regard to foreign business. The same number of furnaces are still in blast, and unless the demand improves stocks will begin to accumulate. Prices are the turn easier, and the following may be taken as to-day's quotations:—Hematite, 6*l.* 7*s.* 6*d.* per ton, delivered at the steel works; foundry iron, No. 1, 6*l.* 2*s.* 6*d.* per ton, and No. 3, 5*l.* 17*s.* 6*d.* per ton, both on trucks at makers' yards.

Scottish Pig-Iron Shipments.—There has been a gradual decrease in the shipment of Scottish pig-iron of late, and the figures for the past week bear this out. The total shipped from Glasgow Harbour for the week ending last Saturday, May 12, was 928 tons, of which 877 tons went foreign and the balance of 51 tons went coastwise. The figures for the corresponding week of last year were 302 tons foreign and 106 tons coastwise, making a total of 408 tons.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Exports of coal as cargo from South Wales in April amounted to 2,451,842 tons, or 350,000 tons less than in March. The daily rate of shipment in April was, however, higher than in March, owing to the incidence of holidays in the former month, by which the number of working days was reduced to 23 as compared with 27 in March. In April the daily rate of shipment amounted to 106,610 tons, against 103,810 tons in the previous month. The shipments in the first four months of this and last year are shown below:—

Month.	1922. Tons.	1923. Tons.
January	1,858,615	2,432,706
February	1,787,738	2,291,437
March	2,145,558	2,803,783
April	1,753,002	2,451,842
Totals	7,544,913	9,979,769

It will be seen from the above that the exports in each month of this year have been considerably greater than in the corresponding period of last year, and that over the four months there is an increase of 2,434,800 tons, or about 32 per cent. The destination of the April shipments during this and last year is given below:—

South Wales to:	April, 1922. Tons.	April, 1923. Tons.
France	531,319	908,534
Italy	261,295	396,273
South America	262,396	285,157
Spain	142,593	117,089
Portugal	77,722	107,687
Greece	6,031	41,299
British coaling depots ...	175,306	160,476
Other countries ...	296,340	425,327
Totals	1,753,002	2,451,842

Of the exports to other countries in April last, 25,542 tons went to the United States, 35,332 tons to Belgium, 69,845 tons to Holland, 168,143 tons to Germany and 76,465 tons to unclassified destinations. During the past week market prices have advanced and free supplies of coal were scarcer. For the best Admiralty large 42*s.* 6*d.* is firmly demanded, 40*s.* for Monmouthshires, and 32*s.* 6*d.* for best bunker smalls. The inquiry for delivery over the second half of the year is also more active. One of the Brazilian Railways want offers for 360,000 tons of large over the eight months ended December, and the Egyptian State Railways are inviting tenders for 120,000 tons, and alternatively, 160,000 tons of Welsh coal, delivery to commence in July.

Iron and Steel.—There was an improvement in the volume of the iron and steel export trade last week. Shipments of tin plates and terne plates amounted to 11,939 tons, compared with 9,929 tons in the previous week, black plates and sheets to 7,776 tons against 5,399 tons, galvanised sheets to 1,632 tons against 1,362 tons, and other iron and steel goods to 4,414 tons against 1,492 tons.

THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—With reference to our paragraph on page 587 *ante*, further meetings are now announced, of the South-Western District, at St. Austell, Cornwall, on the 26th inst., of the Scottish District, at Stirling, on June 8 and 9, and the fiftieth annual general meeting and conference, at Leeds, on June 27 to 30.

RATE OF DISTILLATION AND QUALITY OF SHALE OILS.—Studies made by the United States Department of the Interior at the oil shale laboratory of the Bureau of Mines, Boulder, Colorado, indicate that the changes in the quality of crude shale oils produced by varying the rate of distillation, may be due to (*a*) the temperature at which the decomposition took place, and (*b*) the extent to which the thermal reaction progressed. The temperature studies show conclusively that the oils produced at the slow rates of distillation are actually produced at much lower temperatures than the oils formed by rapid distillation. The practical limits to which controlled cracking within the retort may be carried are not yet determined, but since time or temperature are such important factors in the production of good crude shale oils, it should be feasible in commercial retort design to balance size of retort and heating surface, rate of heat supply to the shale, size of shale particles, and rate of working, so that the most desirable rate of distillation and subsequent thermal reactions can be obtained. Thus, it should be possible to govern, within fairly wide limits, the qualities of the crude oils obtained, and thereby to produce crude oils of the most desirable properties for commercial needs.

RAPID CARGO SHIP BUILDING.—Messrs. Swan, Hunter and Wigham Richardson, Limited, who control 48 building berths for steamers up to 1,000 ft. in length, have within five months built and finished eight out of nine steamers building for Canada, and have despatched the eight vessels completed to the St. Lawrence within the last month. Five of the ships were built at their Wallsend shipyard, one at their Neptune shipyard, one at their Southwick shipyard, Sunderland, and one at their Clydeholm yard, Glasgow. The ninth vessel is being built at their Londonderry yard. The rapid construction of these steamers was undertaken with a view to their completion in time for the opening of the St. Lawrence spring navigation, and it is expected that they will all arrive in time. The boats are about 250 ft. long, 42 ft. 6 in. broad, and 20 ft. 6 in. deep. There is a raised quarter deck 100 ft. long and 4 ft. deep, and a forecastle 35 ft. 6 in. long. The engines have been supplied by Messrs. Swan, Hunter and Wigham Richardson, Limited, Messrs. MacColl and Pollock, Limited, Messrs. R. and W. Hawthorn Leslie and Co., Limited, Messrs. Barclay, Curle and Co., Limited, and Messrs. J. G. Kincaid and Co., Limited.

COKING OF OIL SHALES.—Results of retort studies in the oil shale laboratory of the United States Department of the Interior at Boulder, Colorado, have been tabulated and will serve as the basis for a report to be prepared by engineers of the Bureau of Mines. In connection with this work, very interesting information regarding the coking of different shales has been accumulated. The sample of Australian shale which yields over 120 gallons of oil to the ton has only a slight tendency to coke in the retort. The 60-gallon Elko, Nevada, shale has no tendency to coke. The 65-gallon massive shale from De Beque, Colorado, shrinks to half its size and apparently melts down in the retorting process, and the resultant coke adheres most tenaciously to the retort walls, being difficult to remove. Another massive shale from the same locality, but 600 ft. or 700 ft. higher in the series, yielding about 60 gallons of oil to the ton, shows only a slight tendency to coke. The 50-gallon Soldier Summit shale has no tendency to coke, and the 34-gallon standard De Beque shale shows only a slight tendency to coke. It is thus apparent that the richness of the shale is no indicator of its coking tendency. An interesting problem opened up is to determine if possible what characteristics of the shale indicate tendency to coke and what measures may be taken to prevent coking. The particular De Beque shale which cokes so badly seemingly represents the richest workable deposit in that district, so the solution of this problem is likely to have results of very great importance. Analytical distillations were made on the shale oil produced by the assay retorts from the Australian shale and on the oil produced by running to coke Australian shale produced by a commercial plant. The results are exactly parallel to results of similar studies on American and Scotch oils.

NOTICES OF MEETINGS.

THE NEWCOMEN SOCIETY.—Wednesday, May 23, at 5.30 p.m., at Prince Henry's Room, 17, Fleet-street, E.C. 1. Paper by Mr. J. E. Hodgson, Member, "Some Notes on Sir George Cayley as a Pioneer of Aeronautics."

THE OPTICAL SOCIETY.—Thursday, May 24, at 7.30 p.m., at the Imperial College, Imperial Institute-road, South Kensington, S.W. 7. Lectures on the "Evolution and Development of Optical Instruments." Lecture No. VI, "Telescopes from a Historical Standpoint," by Mr. David Baxandall, A.R.C.S. The lecture will be illustrated by exhibits from the collection in the Science Museum, Kensington.

THE INSTITUTION OF STRUCTURAL ENGINEERS.—Thursday, May 24, at 7.30 p.m., at Denison House, 296, Vauxhall Bridge-road, S.W. 1. Annual General Meeting. Paper on "Some Recent Tests on Concrete and Earth Pressures," by Dr. Oscar Faber.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 25, at 9 p.m., at Albemarle-street, Piccadilly, W. 1. Evening discourse will be delivered by Sir Aston Webb, K.C.V.O., C.B. The subject is "The Development of London." Afternoon Lecture, at 3 p.m., Thursday, May 24, Professor E. G. Coker, D.Sc., F.R.S., on "Engineering Problems Solved by Photo-Elastic Methods" (Lecture II).

FOREIGN SAMPLES EXHIBITION AT WALSALL.—An Exhibition of Foreign Samples and Catalogues held at the offices of the Walsall Chamber of Commerce on the 3rd and 4th inst. proved one of the most successful displays yet held at that centre. The samples exhibited proved of exceptional interest to the manufacturers of Walsall and district, who expressed their ability to compete with the foreign-made articles.

PERSONAL.—Messrs. Beyer, Peacock and Co., Limited, Gorton, Manchester, have removed their London office from 15, Dean's-yard to Abbey House (Rooms 338–340), Westminster, S.W. Mr. W. C. Williams is acting as their representative.—Messrs. Henry Berry and Co., Limited, Leeds, have opened an office at Central House, 75, New-street, Birmingham. Telegrams: "Rivetter, Birmingham." Telephone No. 4317 Central, Birmingham.

SWEDISH SALVAGE ENTERPRISE.—The Gothenburg Salvage Company, it is reported, has entered upon a contract with Lloyd's concerning an attempt to salve the Egypt, which sank, about a year ago, after a collision with the Seine. The Egypt is now lying at a depth of 65 fathoms, 20 nautical miles from Ushant. The P and O. boat had 1,000,000*l.* in gold and silver on board. The conditions are "no cure, no pay," and in case of success 55 per cent. of the value recovered. Special appliances will have to be constructed; the tidal difference is as much as 24 feet, and the current has a speed of up to 4 knots. The first problem is to locate the wreck, for the collision took place in a fog. The Swedish Company will employ the Frithiof, built in 1921, equipped with two Diesel engines, each of 650 h.p., and the pumps have a capacity of 6,000 tons per hour. Experts are anything but sanguine as to the outcome of the venture.

MOTOR RAIL CARS.—According to a report in the Norwegian journal *Aftenposten*, the Norwegian State Railways have ordered from Germany three rail cars driven by motor spirit which are to be put on trial this year. One car has been ordered from A.E.G., Berlin, for delivery by December 10 next. This car is carried on two axles; the other two, which are on four axles, have been ordered from Deutsche Werke, Kiel, for delivery by October 10. It is stated that these rail cars will be cheaper to run than ordinary locomotives, but they cannot well be used except on lines where traffic is small and where steam power is disproportionately dear. The cars ordered from Deutsche Werke are said to be 19½ m. long, 2·75 m. broad, 3·85 m. high, and to weigh 18 tons; there is seating accommodation for 70 passengers. A cutting from the *Aftenposten* showing the type of car ordered from the Deutsche Werke can be inspected by British firms interested on application at the Department of Overseas Trade (Room 50), 35, Old Queen-street, Westminster, London, S.W. 1.

SAFETY DEVICES FOR CIRCULATING SYSTEMS.—Mr. C. L. Stokoe writes to us regarding our description of his safety devices for circulating systems, on pages 584 and 585 of last week's issue, as follows: Your reference on page 584, column 3, to "only a small head being dealt with," holds good for most cases, but I have in operation several "Monitor" valves in the pipe line of town mains supply where pressures up to 120 lb. per square inch may be expected. It is evident that a "Monitor" valve situated between a pump and a shut-off valve will be subject to the full pressure of pump if the shut-off valve is inadvertently closed and it is intended that the safety device should operate even under this condition. The balanced type of spindle, Figs. 8 and 9, is remarkably effective, and I think the reason of the fluid-tightness of the washers is that the internal pressure compresses them on to the spindle diameter and at the same time presses the washer material firmly against the face of the bearings. If any leakage is likely it is at the compression spring end, where the washer can be very quickly renewed with plant at work. Leakage also can be led away by the end connection. I find with carefully constructed fittings that there is no leakage whatever at the "operating" end of the spindle.

FLOATING PNEUMATIC GRAIN-DISCHARGING PLANT.

CONSTRUCTED BY MESSRS. HENRY SIMON, LIMITED, ENGINEERS, MANCHESTER.

(*For Description, see Page* 608.)

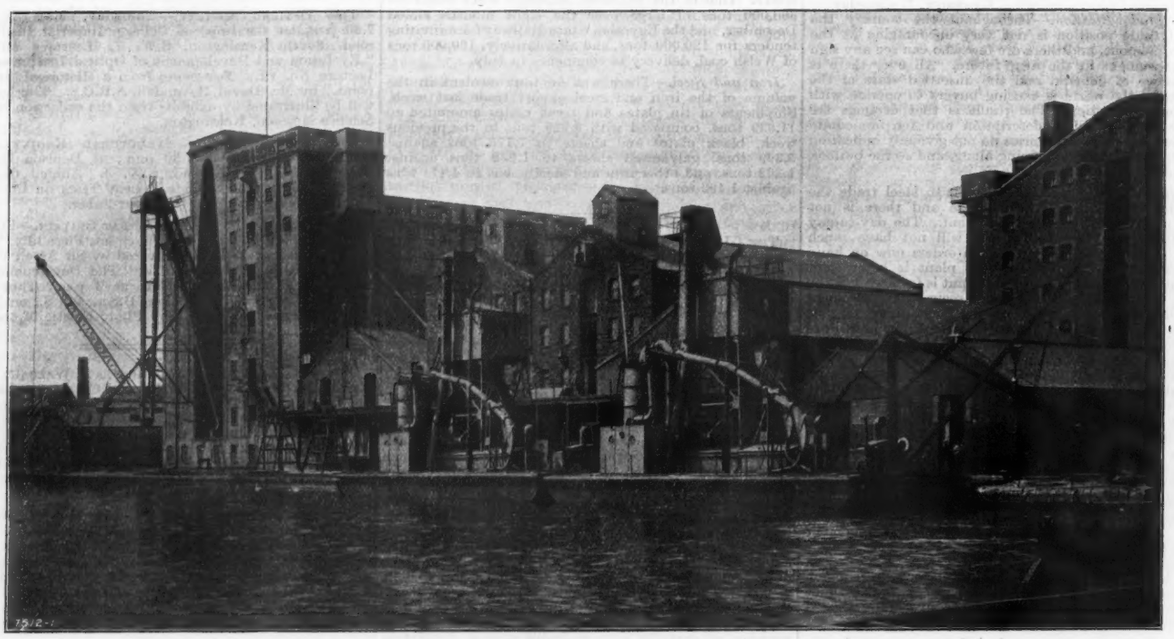


FIG. 33. STARBOARD SIDE OF FLOATING ELEVATORS.

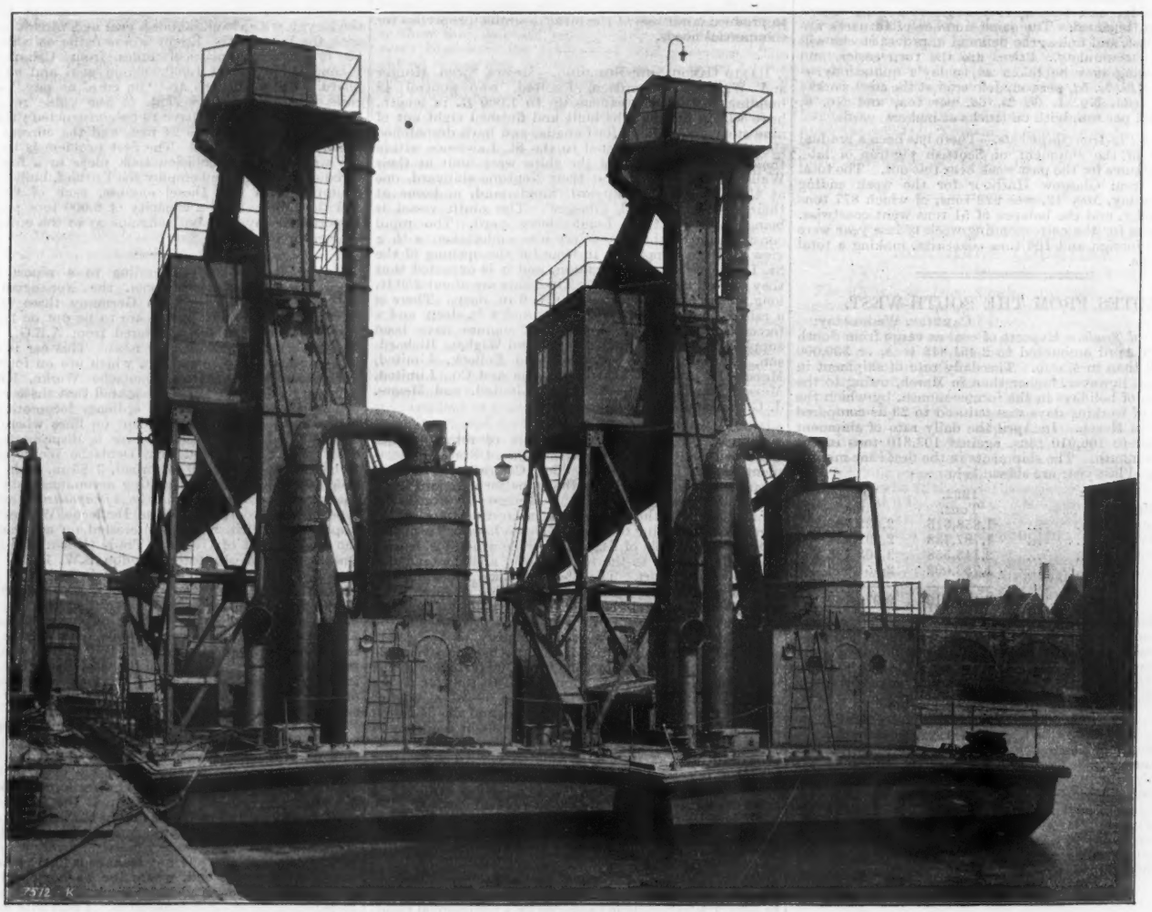
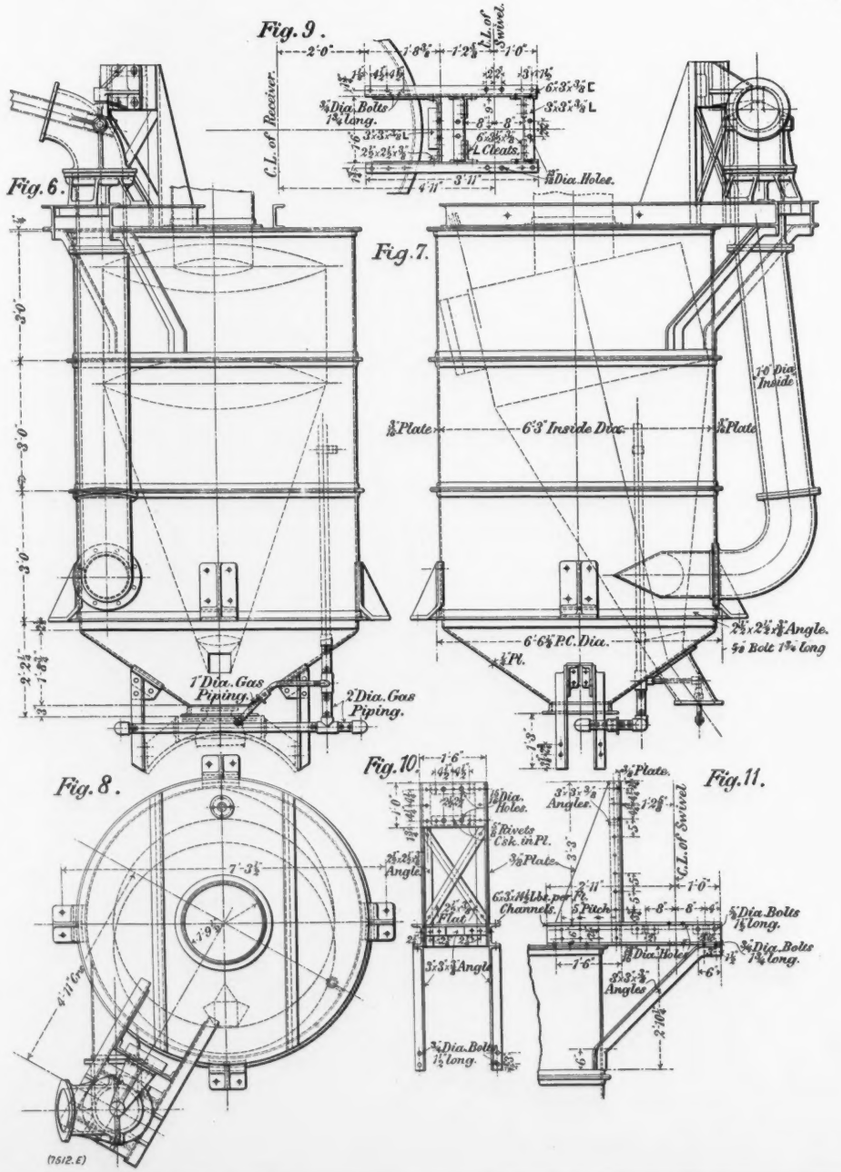


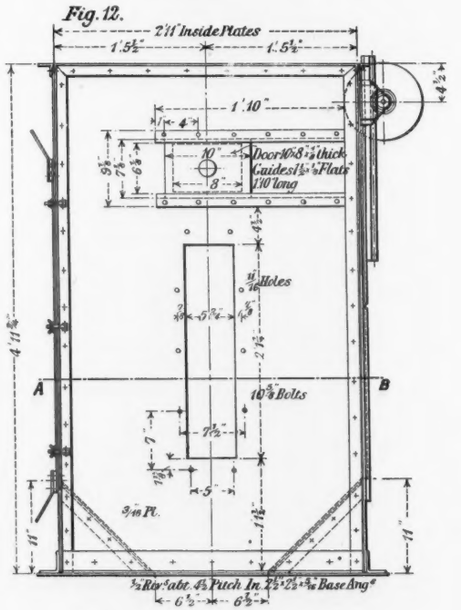
FIG. 34. BOW VIEW OF FLOATING ELEVATORS.

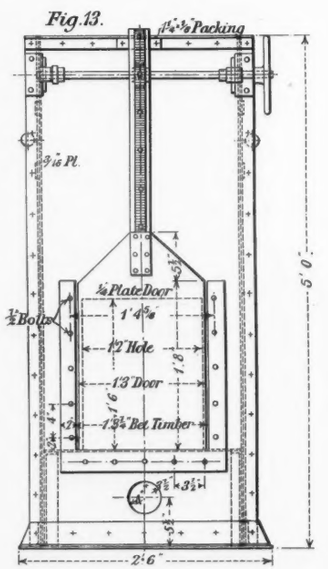
FLOATING PNEUMATIC GRAIN-DISCHARGING PLANT FOR MESSRS. SPILLERS AND BAKERS, LIMITED, CARDIFF.

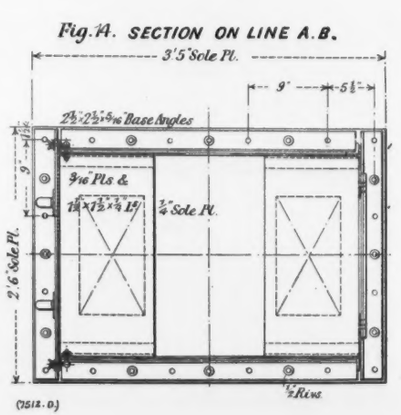
CONSTRUCTED BY MESSRS. HENRY SIMON LIMITED, ENGINEERS, MANCHESTER.

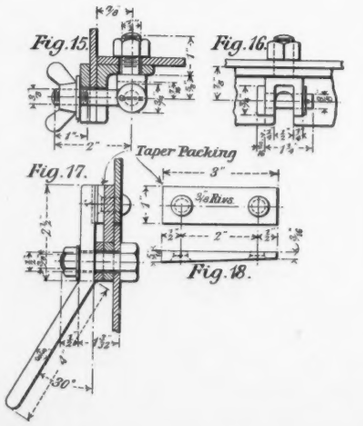
(*For Description, see Page* 608.)











FLOATING PNEUMATIC GRAIN-DISCHARGING PLANT FOR M

CONSTRUCTED BY MESSRS. HENRY SIS, LIM

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Fig. 1. SIDE ELEVATION. PONTOON, SIDE-PLATE REMOVED.

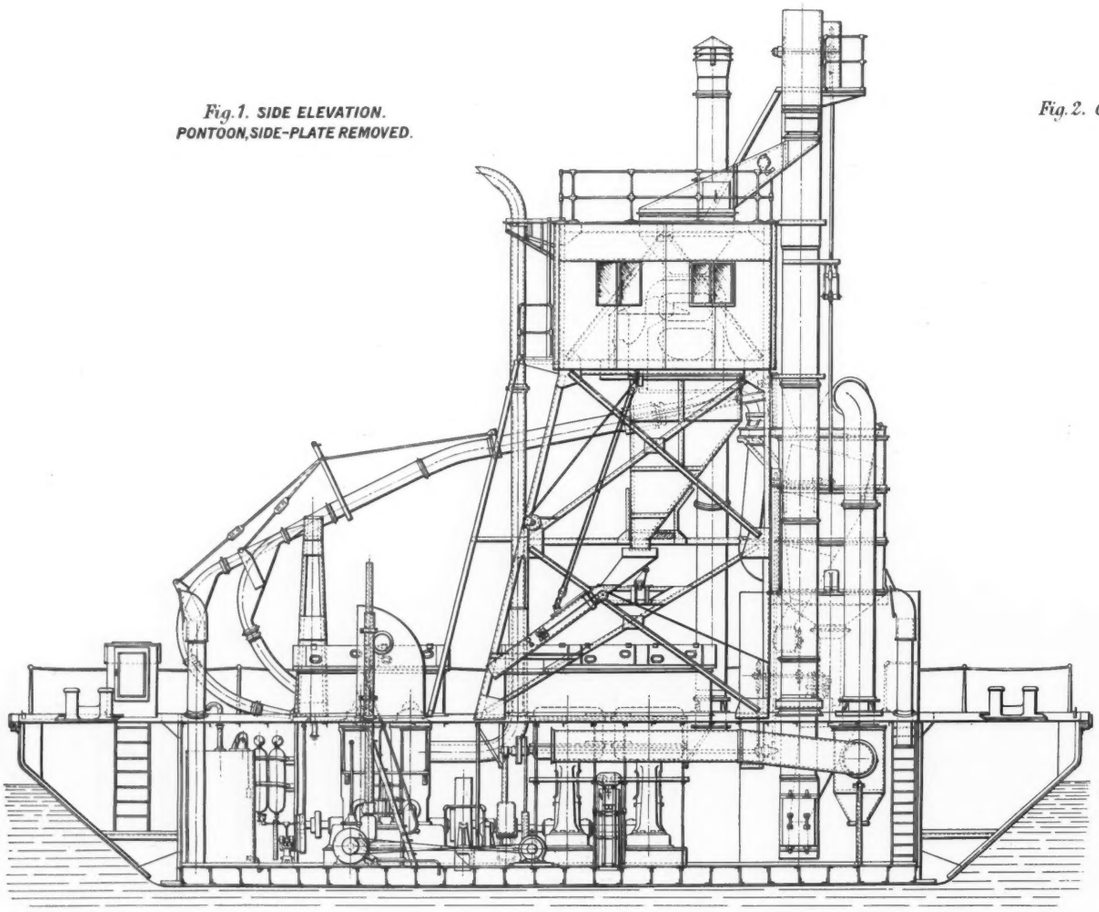

Fig. 2. CROSS SECTION.

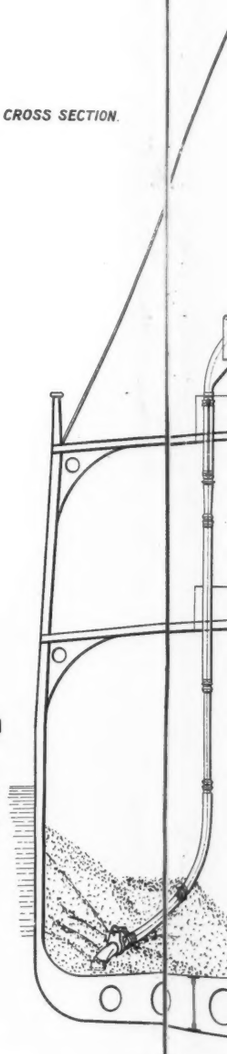

Fig. 3. PLAN ABOVE DECK.

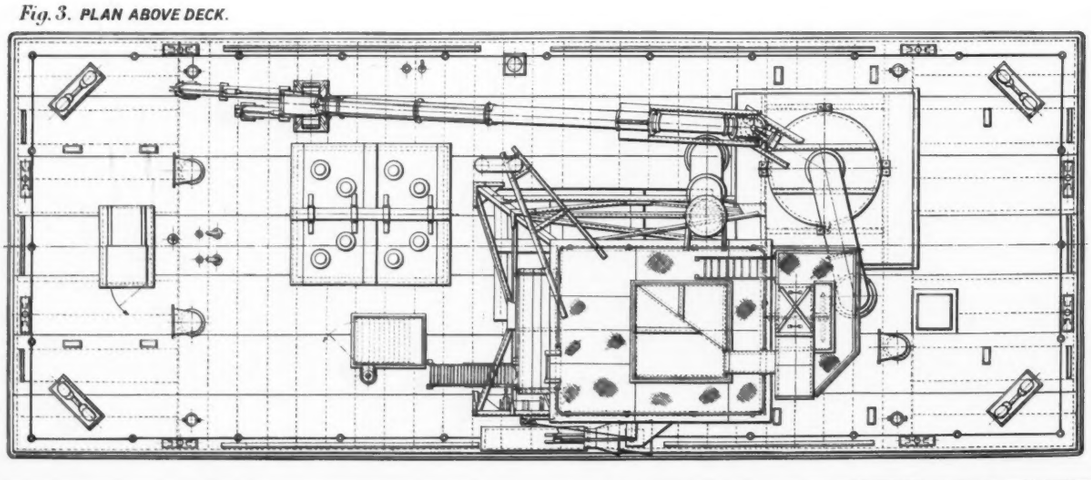

Fig. 4. PLAN

T F R MESSRS. SPILLERS AND BAKERS, LIMITED, CARDIFF.

ENRY SIM, LIMITED, ENGINEERS, MANCHESTER.

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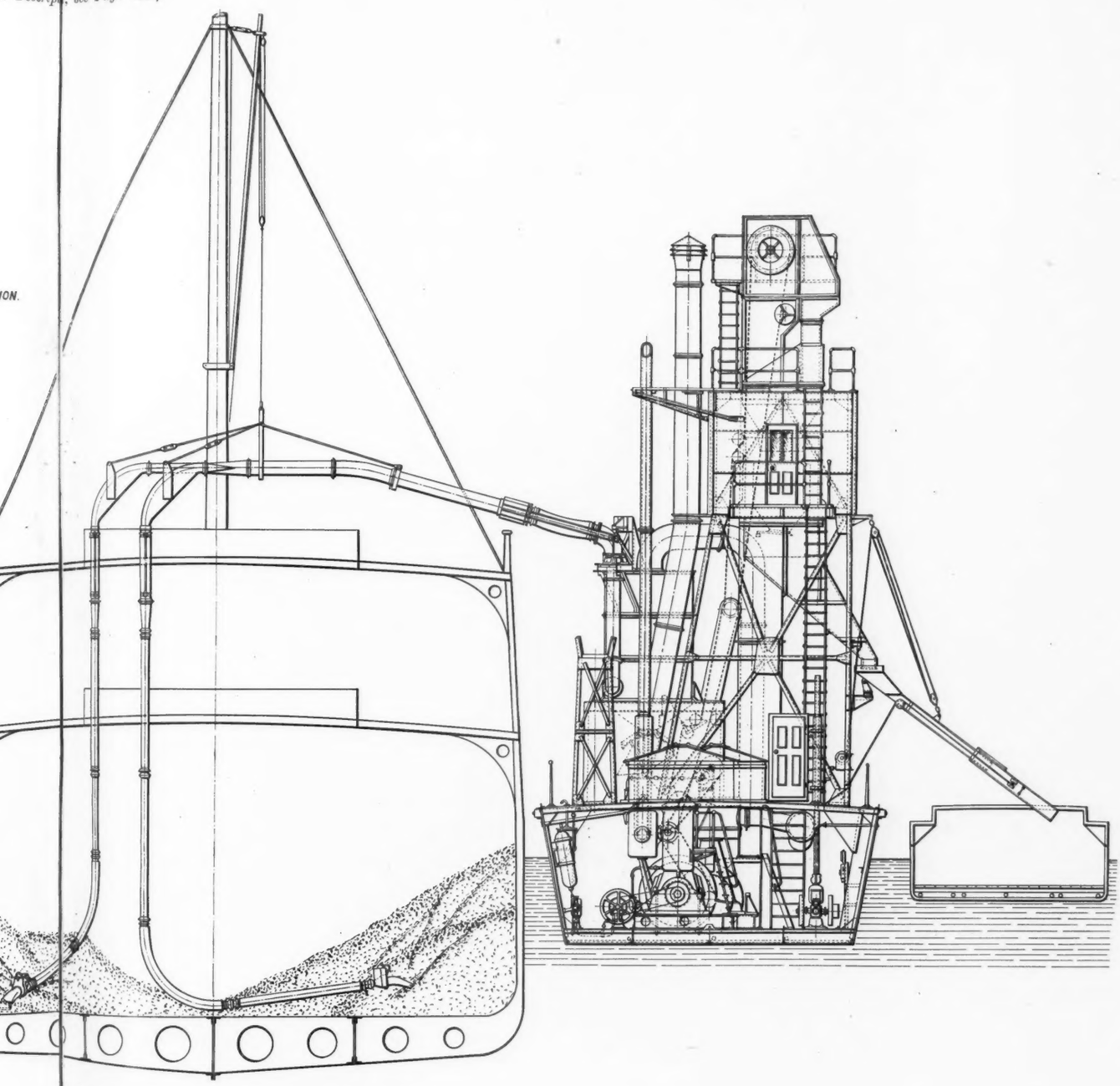
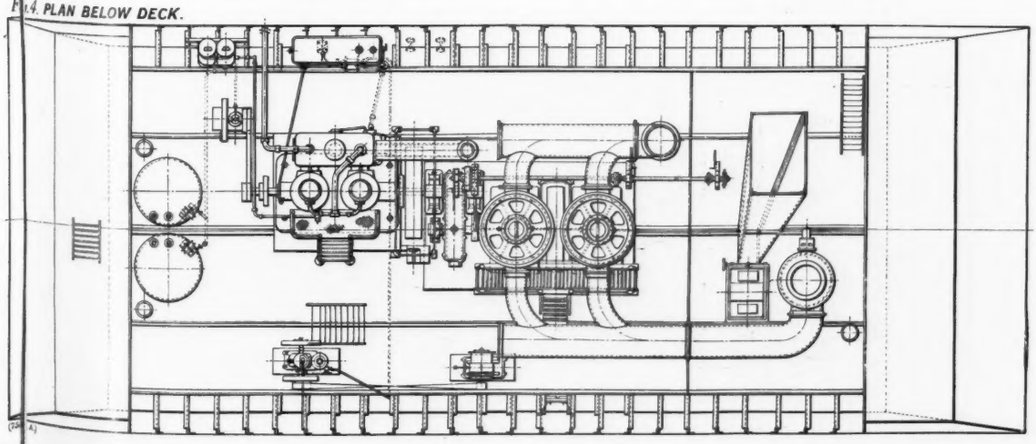


Fig 4. PLAN BELOW DECK.



DETAILS OF FLOATING GRAIN-DISCHARGING PLANT.

CONSTRUCTED BY MESSRS. HENRY SIMON, LIMITED, ENGINEERS, MANCHESTER.

(*For Description, see Page* 608.)

Fig. 19. FRONT ELEVATION. STARBOARD SIDE.

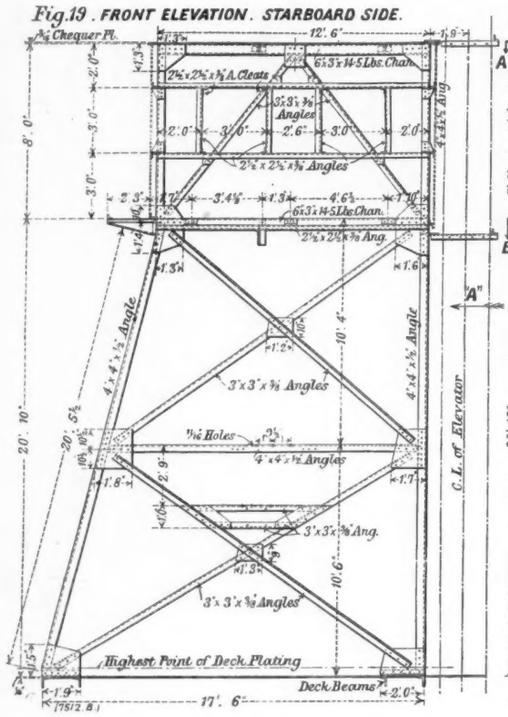


Fig. 20. END ELEVATION LOOKING IN DIRECTION OF ARROW "A".

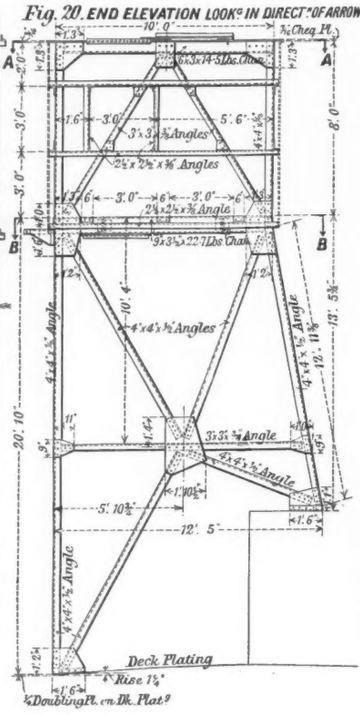


Fig. 21. PLAN ON A.A.

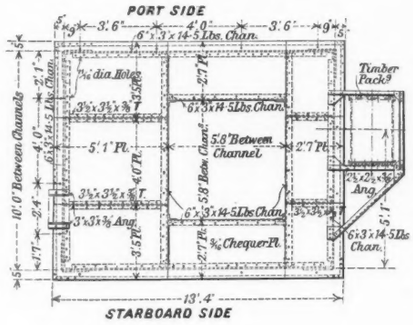


Fig. 22. PLAN ON B.B.

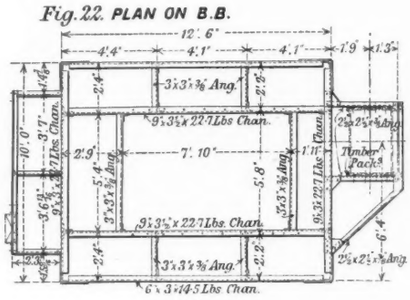


Fig. 23.

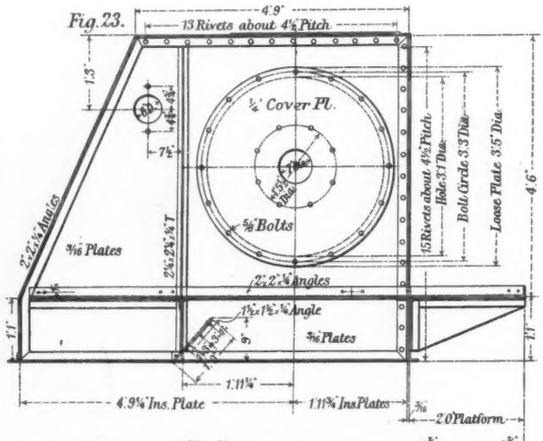


Fig. 24.

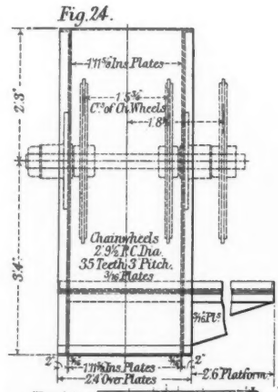


Fig. 25.

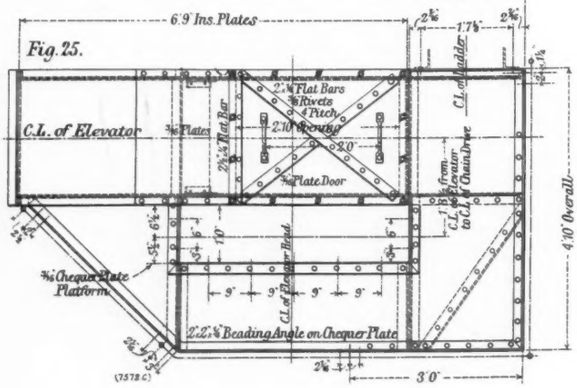
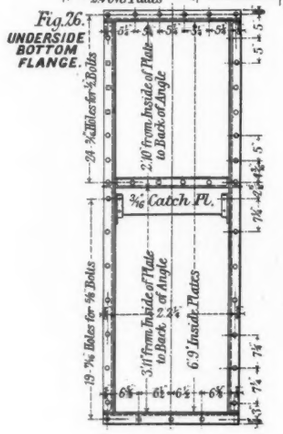


Fig. 26.


UNDERSIDE BOTTOM FLANGE
24 ¾" Holes for ¾" Bolts
2'. 10" from Inside of Plate to Back of Angle
⅜" Catch Pl.
3'. 11" from Inside of Plate to Back of Angle
6'. 9" Inside Plates
19 ¾" Holes for ¾" Bolts

(*To face page* 609.)

ENGINEERING.

Offices for Publication and Advertisements, 35 and 36, Bedford Street, Strand, London, W.C.2.

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity of going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

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One Two-Page Plate and Two One-Page Plates.—*FLOATING PNEUMATIC GRAIN-DISCHARGING PLANT FOR MESSRS. SPILLERS AND BAKERS, LIMITED, CARDIFF.*

DEATH.

Suddenly at Birling Gap, Eastbourne, on May 1, Harry Llewelyn Davies, Chairman of Cochran and Co., Annan, Ltd.

ENGINEERING.

FRIDAY, MAY 18, 1923.

THE SUPPLY OF FOREMEN.

OF the many problems connected with works administration those centering round the position and duties of the foreman have caused some of the keenest discussion. It is generally recognised that the present situation is not all that it might be, and that the old-time type of foreman is far from being ideal in a modern factory. Nevertheless it has been found exceedingly difficult to make any change. The type of man actually required is almost impossible to obtain and, though the old-type foreman does not fill the post to perfection, almost every other class of man who has been tried has done worse. The most fundamental change was made by Taylor, but though his notion of the "functional foreman" was possibly sound at bottom, and worked well under Taylor's own direction, it has been found to be too complicated for general use, up to the present time.

The fact that a foreman has to deal chiefly with the difficulties and capabilities of workmen points to the choice of a superior man of that class. The promotion of a good workman has the great advantages that the foreman then has an expert knowledge of the trade carried on by his men, and is thus a good judge of their ability and industry, and, moreover, being of the same social class and of the same upbringing and training, he can enter with real sympathy into the difficulties of the man and, by timely encouragement or admonition, can maintain a corporate spirit in the shop and avoid too frequent changes of *personnel*. But though these advantages are very great, and usually result in the choice of a superior workman to fill such posts, some of the essentials for really satisfactory work are missing.

The training of the British artisan is thorough, but it is, unfortunately, narrow. The breadth of trade knowledge desirable in an officer of an important concern is seldom acquired, and still less the requisite general knowledge. The absence of these things, is chiefly felt in the effect upon the mentality of the foreman ; for here the narrowness of training is reflected in narrowness of outlook and inflexibility. Thus it usually happens that, where a management is progressive, their programme of advance is continually being held up because the permeability of the foreman to ideas is too small ; where they rely on the initiative of the foreman to develop his own ideas the result is generally nil.

The choice of a foreman is extremely important because of the immense power of that officer to affect the affairs of the works for better or for worse. Although the post is not one of very high rank it joins up the activities of the two great branches of a factory ; the devising and directing, and the actual producing. It is on the effective co-operation of these two functions that success depends and, consequently, the position of the foreman is a much more important one than appears to be generally admitted. If the foreman chosen is a strongly practical man and a good disciplinarian that is all to the good, but if he is of such a temperament that he opposes all innovations he will not be a success from the point of view of the management. Yet this is, too frequently, what happens. The opposition of the foreman to the new ideas originating from "above" is seldom open but, nevertheless, it exists. The men soon discover this and act in concert to abet their foreman in resisting innovations against which they, too, are prejudiced. The foreman may be got to acquiesce in the introduction of something new, but mere acquiescence is of comparatively little use. What is required is intelligence to perceive the new conception and ability to introduce it into the department ; for in all such matters the foreman is the only effective go-between for introducing the ideas of the management to the men. It is as though the workmen spoke one language and the management another, the foreman being the necessary interpreter.

It follows, then, that the foreman must be capable of analysing two differing types of expression for, not only must he introduce the ideas of the management to the shop, but he must interpret the objections of the shop to the management. In many cases it happens that the management explains a proposal to the foreman ; the foreman knows instinctively, from his lifelong connection with the shop, that the proposal will not work ; yet he cannot say why, and, consequently, offers a kind of grudging acceptance, which is of no use either to himself or to the management. What is required in this connection is a more analytical type of mind in the foreman. This, however, is seldom found in connection with the trade knowledge and powers of control also required for the post.

While the realisation of the deficiencies of the old type of foreman has been growing, there have been important developments in quite another field at first apparently unconnected. During the past twenty years a considerable change has taken place in the facilities afforded for training University graduates. In particular, the facilities for obtaining a degree in engineering have greatly increased. Extensions have been made in the departments of the older Universities, and, in addition, new universities and university colleges have been formed. There has also been a tendency to enable part of the degree course to be undertaken at a technical school, in either day or evening courses, and a number of the better equipped technical schools prepare candidates for the complete degree course.

The graduates of universities are of many different types and by no means all are marked out to be captains of industry on the one hand or mathematicians on the other. Quite a large number have the constructive and practical type of mind, and of these a good percentage might be found with latent ability of control. What is the employer to do with this kind of man ? At present he usually drifts into office work of some kind, and finding no adequate use for the knowledge he acquired at college, he rapidly forgets it and to a large extent his education and abilities are wasted. For the type of man we have in mind, it is possible that a foreman's career might be the best road to such further promotion on the executive staff as his abilities might warrant. The thorough practical knowledge of his trade, which is essential to a foreman, cannot however be attained in any academy of learning, and only

in very rare cases is it ever acquired afterwards. A trade can only be learnt by the fingers and transmitted by them to the brain, and all experience shows that the receptive mind of early youth is the best soil in which to implant the practical knowledge of workshop processes.

Young men who have served a thorough apprenticeship in the works before going to a university, and thus acquired that intimate knowledge, not only of mechanical processes, but of the minds and methods of thought of the workmen, have usually little difficulty in obtaining employment afterwards, for they are useful to an employer in many capacities. If given a job in the drawing office they can be trusted to apply the touchstone of practical experience of manufacture to the attractive design based on theoretical knowledge. They could equally safely be trusted with the responsibility of outside erecting work, in which unforeseen difficulties, whether with men or materials, have to be overcome as they arise, and in short they are well on the road to as high a position in the industry or profession of engineering, as their natural strength of character will lead them to. Such men, if their inclinations tended that way, or if no other course appeared open at the time, might well be given a post of minor executive duty in a large shop, as assistant foreman, and they would probably soon be capable of taking complete charge of some small department. With increasing age and experience, they would develop into foremen of the best possible type, understanding both the minds of the management and of the workmen, and capable of interpreting one to the other, in addition to carrying out their practical duties effectively. The only trouble would be that they might soon leave the non-commissioned ranks of foremanship, for a status of wider authority, and more amenities. The need for foremen is, however, vastly greater than that of works managers, and it might be that by a truer appreciation of the value of good foremen and a corresponding increase in their status and emoluments, a large number of men with sound theoretical training might be induced to occupy such positions.

The average college graduate is, however, far too lightly equipped with practical knowledge to be entrusted with the least authority over skilled or even unskilled workmen. He would be a source either of merriment or irritation to the men and all effective discipline would be at an end. Only an infinitesimal portion of his text-book information would be of any use at all in his daily duties, and he would find himself deficient in all that kind of real knowledge necessary to the proper handling of the men and materials under his charge. There are, however, hundreds or thousands of graduates of this kind leaving the engineering colleges, and the problem of usefully absorbing them into industry is a pressing one. Those with pronounced mathematical or other ability are very few indeed, and they need not be considered, as they would get on in any case. Of the vast remainder, too many think that their degree is *prima facie* evidence that they are engineers, and that industry owes them an agreeable and respectable livelihood for having obtained it. If disillusionment comes early enough and teaches its lessons aright, all may yet be well. These men have, in a sense, started to learn the profession of an engineer from the wrong end, and their first endeavour should be to become acquainted with the real nature of the things of which they have learnt the theory.

It is admittedly difficult for a university graduate to take his place in the shops and humbly learn how tools are used from men to whom he may mistakenly think that he is superior. The attitude of mind which comes natural to a boy, is impossible for him by reason of his age, and it is thus all the more difficult for him to establish proper and friendly relationship with the workmen, upon whom after all he has to depend for instruction. Nevertheless, to be a real engineer, practical knowledge has to be acquired by doing arduous and dirty work, and this would be more palatable to the graduate if he could see that it would lead ultimately to some position in which his university acquirements might be utilised. If more graduates would look upon the shops as their career, rather than aspiring to becoming teachers, it would be greatly to the advantage of the industry. The superior education of the graduate, if added to by an intimate knowledge of workshops and their processes, would soon result in the promotion of its possessor to some more or less authoritative position, and might result eventually in the general acceptance of the view that the highest executive positions in manufacturing establishments were naturally recruited from the ranks of foremen. The foreman's job at present is the culmination of a career, and worthy of respect though it is, it would be but the stepping stone to higher posts if men of better education would fit themselves for foremanships in the only way possible.

"CIMENT FONDU."

THE first results of independent tests of *Ciment fondu*, to be published, so far as we are aware, in this country were given in a paper read by Mr. H. J. Davey on Friday, the 11th inst., before the Institution of Engineering Inspection. We described this somewhat remarkable high-alumina cement, and the uses to which it is being applied abroad, in an article in our issue of August 11th last, page 180, and Mr. Davey's paper confirms very completely the claims to which we then directed attention. An independent chemical analysis by Mr. H. F. Knight, included in the paper, also agrees closely with figures previously published, except that the percentage of iron given is somewhat smaller than the reputed average for the new cement.

Mr. Davey appears throughout to have been working with rather small quantities, and for this reason his tests had to be confined to what might be termed key points, instead of covering completely a wider range. They are adequate, however, to illustrate conclusively the quick hardening property of the material, though they do not make clear what happens after a prolonged period. The tests on neat cement and on cement mortar made by Mr. Davey both show that full strength is reached in a very short period, approximately in the proportion of hours to the days for Portland cement; they also seem to indicate that there is some slight falling off subsequently from the maximum. This is a point upon which it would be interesting to have further data, as it is naturally one to which some importance must attach if the fall should prove at all serious. We do not believe that this is actually the case, and Mr. Davey's tests are hardly carried far enough to be conclusive on this point, while the author admits having information going to show that the curve soon levels off. As the rate of decrease is very slight this would imply only a small loss. In any case, the margin between *Ciment fondu* and Portland cement is so large that a small recession from the maximum strength of the former would be immaterial. The tensile tests given at the meeting last Friday showed a rather irregular curve for neat *Ciment fondu* briquettes with values ranging between 822 lb. and 1,003 lb. per square in. at intervals up to 91 days. The tests for *Ciment fondu* mortar were more regular and gave a value of 565 lb. at 1 day up to 659 lb. at 28 days, followed by the slight fall to which we have referred above. The chief point made by Mr. Davey is the "entirely unexpected verification," as he states it, of the claims made with regard to quick hardening.

Following up the tensile tests, Mr. Davey carried out some crushing tests, but again with only limited quantities of the material. These tests, however, also confirmed the rapidity of the hardening of this cement. Two 6-in. cubes were made with 1 part of *Ciment fondu*, 2 of Ham River grit, and 4 of Ham River shingle. After 26 hours the first cube was tested and failed under a load of 7,730 lb. per square inch, or 510 tons per square ft. The London Building Act requires 1 : 2 : 4 concrete to withstand 1,600 lb. per square inch at one month and 2,400 lb. at 4 months; the difference in resistance is thus very marked. The second cube was crushed when 90 days old, and failed at 9,100 lb. per square inch, or 585·2 tons per square ft. The actual failure occurred very suddenly, pieces of shingle being sheared through. It will thus be seen that this concrete had acquired what, compared with ordinary practice, is an extraordinary degree of strength when only one day old, an age at which Portland cement concrete could not be removed from the mould.

We might refer to other points in our article of last year for which confirmation is to be found in the paper under notice, as, for instance, the degree of heat developed in the setting, or the quickness of setting if free lime be present. Mr. Davey mentions that mixtures of *Ciment fondu* and Portland cement set, on the addition of water, so quickly that they could not be put into moulds without breaking up. The importance of keeping the high-alumina cement free from accidental adulteration by Portland cement is thus emphasised.

In view of the possible utility of a material with such characteristics for particular classes of work where economy of time, or other factors, such as a decreased cost of shuttering, are of importance, it would appear that it should be given a recognised place among materials of construction. The work already accomplished with it on the Continent is so important that it appears to have fully established itself there, but it does not seem to have secured at present any standing in this country. This we believe to be partly due to the fact that supplies are, as yet, only available on a limited scale. The material does not, of course, comply with the British Engineering Standard Specification for Portland cement. It is quite another class of cement, of different ingredients and differing in manufacture, and it was never anticipated that a material of this kind would have to be covered by the cement specification. It seems, however, that *Ciment fondu* has made sufficient progress for it to be given a position in the class of approved materials, so that use may be made of its special qualities where this would prove advantageous. There is possibly more to be known about the new cement and further tests would be welcome, while if it is to come into general use some specification to ensure uniform quality will be required.

Mr. Davey confirms the feasibility of securing good bonding between concrete of *Ciment fondu* and Portland cement concrete. This has been proved to be readily attained with proper precautions, in the reconstruction of concrete buildings in France. It may well happen that with ordinary concrete construction work delays occur owing to the need for allowing some particular section to harden off. If the use of *Ciment fondu* were restricted to parts of this character only, a great saving of time would result and the whole work be expedited. The setting of an arch, for instance, carrying a wall might delay operations. If this essential member were made with *Ciment fondu* concrete the work on the wall could proceed, according to present indications, after about 48 hours or even less. The possibilities of its application to portions of an undertaking in this way are considerable, even if questions of expense or limited supply prevent at present any considerable departure from ordinary practice.

THE ROYAL SOCIETY SOIRÉE.

THOUGH the number of exhibits at the Soirée of the Royal Society, held on Wednesday evening last, the third under the presidency of Sir Charles Sherrington, M.D., was not very large, there were many things of great interest to the engineer. Two of the prominent exhibits, the Boys integrating and recording gas calorimeter, shown by Messrs. J. J. Griffin and Sons, and Professor H. C. H. Carpenter's large aluminium crystals, have been noticed in our columns within the last two weeks. Two demonstrations were given in the course of the evening. The subject of the first of these demonstrations, by Sir Richard Paget, Bart., on the nature and reproduction of vowel sounds, was referred to in our comments on Dr. Eccles' "Notes from a Wireless Laboratory," which appeared on page 530 of our issue of April 27. Sir Richard showed Wheatstone's talking machine in operation, and demonstrated the reproduction of the English vowels with the aid of plasticine models, by blowing air past a vibrating reed to which a double resonator was attached, tuned so as to reproduce the two principal resonances heard in the mouth when the vowel was breathed or whispered. The other demonstration was a remarkable display by Mr. Walter Heape, F.R.S., of films taken by the Heape and Gryll rapid cinema machine designed to take photographs at rates from 500 to 5,000 per second, as used at Shoeburyness for

recording gunnery tests. One of the films showed the extraordinary contortions through which a solid 5-in. rubber ball passes when shot from a 2¼-in. bore gun. Another film illustrated how an electric lamp bulb explodes when struck by a hammer; on the side struck the glass broke into fairly large pieces, on the other side it seemed to be almost pulverised.

We notice in the first instance a few exhibits of historical interest. In commemoration of the centenary of the death of Edward Jenner, the Royal Society displayed Jenner's candidature certificate of 1789; the society further showed photographs of their early meeting places, beginning with Gresham College, 1660 to 1666. The bust of Galileo, exhibited by Mr. G. H. Gabb, executed in pear wood about 1650 or later by an unknown artist, is a wonderfully impressive work of true art; the bust, formerly in the Methuen collection, stands 39 in. high on a globe and socle on which the signs of the Zodiac are carved. The copies of some early scientific instruments, exhibited by the Science Museum, comprised an Egyptian Merkhet of about 700 B.C., used by the horoscope priests to lay out temple axes and in conjunction with a sighting ring to determine the hours of the night. The other Egyptian antiquities were models of water clocks from Karnak about 1400 B.C., and from Edfu, of Ptolemaic period.

The first engineering exhibit to which we pass was the new stream-line filter of Dr. Hele Shaw, in which the liquid is caused to flow with stream-line motion. The filtering material consists of sheets of paper piled upon one another, but the fluid to be filtered does not pass through the substance of the paper, but forces its way sideways through the exceedingly fine spaces left between the superimposed, compressed sheets. The sheets of special paper, of which up to 1,000 go to an inch, are perforated in parallel rows with small and large holes; these holes form vertical channels for the liquid, the solid particles of which are deposited on the rough surfaces of the sheets. In each sheet a large hole acts hydro-dynamically as a source, and while the small holes around it are the sinks, each combination of holes forms a stream-line filter unit. The channels formed by the large holes are closed at the top, the others at the bottom, of the filter-chamber. A special matted or roughened paper is used. From cylindrical filters of this kind, about 2 in. diameter, very turbid blackish oil came out clear and almost colourless, and filtered milk looked like water; strong pressure can be put on the liquid by screwing the cover down. Condensed water is freed of all traces of oil in these filters, which can be washed out without opening them. Stream-line motion was also utilised in the photographs of lines of electric force shown by Mr. E. E. Brooks; some aniline dyes suspended in a dielectric like turpentine give a fair map of the electric field.

The nephelometer of Dr. Fox, shown by the Government Laboratory, although an optical instrument, likewise deals with turbid liquids, but in this case, for determining the degree of turbidity. Two tubes of the same dimensions, containing the liquids to be compared, are placed in the path of a beam of light; over the tubes are two Nicol prisms the polarised beams from which pass into total-reflecting prisms, which reflect them into planes at right angles to one another; the beams then traverse a Lummer-Brodhun cube and are brought into a rotatable Nicol through which the emergent beam enters the observation tube.

The National Physical Laboratory showed X-ray spectra of alloys taken by Dr. E. A. Owen and Mr. G. D. Preston, and photomicrographs, taken by Dr. Kaye and Mr. Higgins, of woods of very low density, the very light balsa wood, the Japanese Kiri wood and others, (used as heat insulators), side by side with pine and beech wood, bringing out the marked difference in the thickness of the cell and also the delicacy of the textures which modern apparatus enables us to study. The iron-mercury calorimeter of Dr. Ezer Griffiths and Mr. Schofield, also of the Laboratory, is a cylindrical block of iron provided with a hole for recovering the specimen and a lid which serves as container for the mercury; the hot specimen is flooded with mercury. The apparatus is useful for testing materials of low thermal conductivity and materials which must not be brought in contact with water.

The apparatus for measuring the compressibility of gases, shown by Dr. Irvine Masson, is a modification, by Messrs. Charles Cook, of Manchester, of the Andrews instrument, and can be used at pressures of 450 atmospheres. The metal body contains four holes, communicating with one another and with a cavity in which a plunger works through a gland; the cavity is full of mercury; into each of the four holes is screwed a glass tube. By screwing the plunger with the aid of a hand wheel, the mercury is made to force the gas into the capillary of a tube; one of the tubes contains the standard gas.

The Anglo-Persian Oil Company demonstrated a test of lubricating oils under electrostatic stress. A block of lithographic stone lies on a copper plate joined to one pole of the electric supply; on the stone is placed a brass disc, 1 in. or more in diameter, which is attached to one beam of a balance; the disc forms the other pole, so that a potential difference of about 120 volts is set up. When the stone is dry it requires about 160 grammes to pull the disc up from the stone against the electrostatic stress; when a fair lubricant is smeared on the stone, the pull is reduced to say 85 grammes; with castor oil a pull of only 10 grammes is needed. The loads mentioned indicate the differences in pull with the electric field on and off.

Amongst the apparatus shown by the Physical Department of the Rothamsted Experimental Station, we notice the modification by Dr. B. A. Keen and the Cambridge and Paul Instrument Company, of the Sven Ode'n balance, with which the rates of sedimentation of suspensions and of flocculation and deflocculation are studied. There was also a new Watson dynamometer, recording the resistance which the plough has to overcome and, at the same time, the depth of the furrow drawn.

Turning to electric exhibits, we may mention the Chladni figures, illustrating the modes of vibration of telephone receiver diaphragms shown by Professors J. T. MacGregor-Morris and E. Mallet. The horizontal diaphragm is excited by alternating currents through a thermoionic valve; sand is thrown on the diaphragm and at least seven modes of vibration can be distinguished by these means within the limits of audition.

Mr. F. Harrison Glew's levitating magnets were very curious—a kind of Mahomet coffin experiment. A rod, about 3 in. long, of magnetised cobalt steel, lies on the bottom of a small glass cell; the cell is placed on the vertical limbs of a strong magnet, so that north pole lies over north pole, and south pole over south pole. The bar is lifted up by repulsion when the cell is lowered into position, and when the bar is pushed down, the bar rises again, keeping horizontal all the time, an inch or so above the poles. With ordinary magnet steel the poles would be reversed when the bar comes too close to the magnet, and this may happen also with cobalt steel, which has then to be remagnetised.

The International Western Electric Company, of London and New York, exhibited the low voltage cathode ray oscillograph, which Sir Ernest Rutherford used during the Royal Institution lectures before Easter* and the Rochelle salt piezo-electric crystals, which make excellent gramophone transmitters. The crystal, about 1⅛ in. high, is varnished; a wire ring to serve as one electrode is twisted round it, half way up; two aluminium plates, on top and bottom, make the other terminal. Between the upper plate and the crystal is interposed another plate, which is struck by the oscillating gramophone needle; the crystal is then twisted, and the deformations cause fluctuations in the electric potential which the electrodes communicate to the telephone receiver, thus reproducing the sounds. If alternating potentials are applied to the crystal, the corresponding deformations will cause acoustic air vibrations in a paper cone fitted to the crystal casing. The water-cooled vacuum tubes of the same company are powerful thermoionic valves of 10 kw. and more, such as were used recently in the Transatlantic telephone tests. The anode is a copper tube, provided with a water jacket; the cathode consists of several parallel tungsten wires, 8 in. long, which are surrounded by a close coil of fine molybdenum wire, forming the grid. Noteworthy is the direct soldered joint between the copper tube and the glass of the cathode tube. The 100 kw. valves are only of double the dimensions (just mentioned) of the 10 kw. valves. We may mention here, further, the direct-reading thermoionic voltmeter of Mr. E. B. Moullin, which measures alternating potentials by utilising the rectifying property of the valve.

Two new uses of phonic motors were exemplified. The phonic motor of Dr. A. B. Wood is part of the mechanism which the Cambridge and Paul Instrument Company has adopted for the chronograph of Dr. W. Rosenhain. The phonic motor, driven by a tuning fork, turns a contact sliding over a rheostat wound on the circumference of a disc, the disc being rotated by the electric motor, which it is to control. We reserve our description of this device. The other phonic wheel, made by the same Company, belongs to the more elaborate chronograph designed by Mr. T. G. Hodgkinson, of the Research Department, Woolwich. Combined with a photographic recorder, it serves for measuring time intervals of the order of 0·001 second in gun calibration. A vane wheel is mounted on the vertical shaft of a small A.C. motor running at a frequency of 1,000 cycles per second, under control of a tuning fork, maintained in oscillation by a three-electrode valve. The 20 vanes of the wheel interrupt the light beam from the lantern, so that on the photographic film a dark band is produced, the vertical divisions of which represent thousands of a second. The four strings of an Einthoven galvanometer cross this band horizontally. The curves of the vibrating string are extraordinarily regular, indicating perfect synchronism between the motor and supply current, which was, moreover, demonstrated with the aid of a stroboscope. Time intervals can accurately be determined to one 10,000th second.

The Research Department had two other novelties on view. The one was Dr. G. West's smoke cloud device for detecting the presence of feeble X-ray beams, such as a crystal would deflect. The idea utilised is that X-rays ionise the air and that some of the ions attach themselves to smoke particles. A puff of ammonium chloride fume is sent by means of a rubber ball into a glass tube, about an inch wide, open at the top; the cloud, first turbulent, settles in a few moments and assumes a flat top, and can then be raised, to a height suitable for observation, by means of a piston. Above that tube is stretched, within the containing glass vessel, a wire charged to a potential of 400 volts. When now X-rays fall on the flat top of the cloud, the ionised smoke particles are drawn up to the wire; it looks as if a small smoke crater had formed. The movement of these particles is observed by means of an ultra-microscope.

The second apparatus is a modification due to Dr. Haughton, late of the National Physical Laboratory, of the Andrews dilatometer for solids at high temperature. The specimen is heated in an electric furnace; the expanding specimen presses against a silica rod, bearing outside the furnace against the steel diaphragm. of a liquid chamber. Instead now of filling this chamber with a coloured liquid as indicator, Dr. Haughton uses mercury and a tube in which a fine wire is placed axially. As the mercury is pushed further, the wire is gradually short-circuited; the wire forms an arm of a Wheatstone bridge which is coupled with a thread recorder. A record of the dilatation is produced simultaneously with a record of the temperature, and the study of the critical points of metals like iron is thus very much facilitated.

(To be continued.)

* ENGINEERING, page 243, *ante*.

GASEOUS COMBUSTION AT HIGH PRESSURES.

IN a lecture delivered at the Royal Institution on Friday evening last Professor W. A. Bone, F.R.S., showed that the nitrogen of the atmosphere does not always play a purely passive rôle in the phenomena of combustion. When the gas burnt is carbon

monoxide and the initial pressure high, the presence of nitrogen greatly retards the rate of explosion, and at the same time reduces the maximum pressure attained, and, moreover, it greatly diminishes the rate of cooling. The upper curve in Fig. 1 represents the pressure curve obtained in exploding a mixture of carbon monoxide mixed with oxygen and nitrogen in about the same proportions as these two gases occur in atmospheric air, whilst the lower curve shows a similar experiment made with hydrogen, nearly the same total energy being developed in the two explosions.

In the case of hydrogen the pressure rose to its maximum value almost instantaneously, and regular cooling ensued immediately this maximum pressure was attained. With the carbon monoxide mixture, on the other hand, the maximum pressure was

Fig. 1.

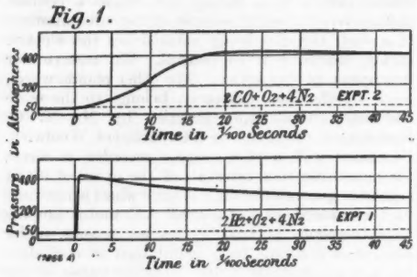
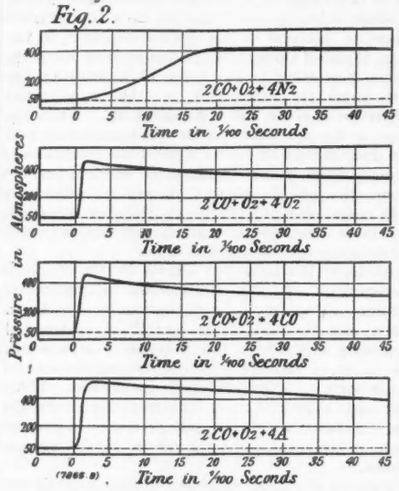


Fig. 2.



attained, but slowly, and was well maintained for a considerable interval of time. In both cases the initial pressure was 50 atmospheres.

At first the difference between the two curves was attributed to the supposed "slow burning" characteristics of carbon monoxide as compared with the quick-burning hydrogen, but when the experiment was repeated with argon in place of nitrogen the rapidity of the combustion was very nearly as great as with hydrogen, and very similar results were obtained when the nitrogen was replaced by an equivalent excess of CO or oxygen. This extraordinary difference between the behaviour of nitrogen and of other diluents is well brought out in Fig. 2, which shows very conclusively that the part played by the nitrogen cannot be merely passive. It is, however, of first importance to note that the addition of a little hydrogen to the mixture of CO and air almost or completely masks or inhibits the effect of the nitrogen and the explosion is nearly as rapid as with hydrogen alone. From these experiments Professor Bone concludes that in a carbon monoxide-air explosion the nitrogen absorbs energy and becomes chemically activated, storing up energy during the earlier stages of the explosion and evolving it slowly again during the subsequent cooling. He has, moreover, also found that when a highly compressed mixture of hydrogen and air is exploded, there is little or no production of nitric acid, whilst when the hydrogen is replaced by carbon monoxide nitric acid is formed, and the yield is higher the higher the initial pressure. Professor Bone suggested that there was here the possibility of forming nitrates from the air by burning at high pressures the carbon monoxide liberated from our blast furnaces, the whole of the energy required for the reaction being provided by the combustion of the monoxide. He expressed the hope that the practicalisation of this process should not be left to foreign organisations.

In some further experiments in which CO was exploded with the amount of oxygen necessary for its complete combustion a temperature of 5,000 deg. C. has been reached, the maximum pressure attained being 237 atmospheres. Professor Bone believes that still higher temperatures may be attained, but for this stronger plant will be needed and for the provision of this funds are not at present available.

In the earlier portion of his lecture, Professor Bone drew attention to the difference in the character of the flame yielded by hydrogen and CO respectively when burning at atmospheric pressure. The hydrogen flame is much less luminous, the radiation of energy from the monoxide flame being 2·4 times as great. A study of the two flames has led him to the conclusion that in flames the hydrogen molecule can react directly with the oxygen molecule, but that the carbon monoxide molecule can only react with the oxygen atom or else with "activated steam."

Professor Bone holds, in short, that an undissociated oxygen molecule on being heated in a flame has its "residual affinities" sufficiently stimulated to enable it to seize on two hydrogen molecules forming an unstable vibratory complex H_4O_2. This complex being in an intensely vibratory condition is assumed to break down instantly into either two molecules of steam, also in a highly vibratory or "activated" condition, or alternatively into two atoms and two H_2 molecules. Both the "activated" steam and these oxygen atoms are, he considers, capable of reacting with the carbon monoxide molecule. The latter, if itself thoroughly dried, will not burn in thoroughly dried air, a fact which Professor Bone demonstrated by inverting a jar of dried air over a flame of CO, which was thereby instantly extinguished.

Reference has already been made to the remarkable effect of small additions of hydrogen to a carbon monoxide-air mixture exploded at a high initial pressure, and Professor Bone has further found that slight additions of hydrogen to carbon monoxide burning at atmospheric pressure entirely alters the character of the flame, rendering it almost as non-luminous as the pure hydrogen flame.

INTERNATIONAL ROADS CONFERENCE.

(*Concluded from page* 591.)

THE method adopted for the discussion of the numerous reports presented was that usually followed at international conferences. Six separate discussions were arranged and an attempt made to reach conclusions on the various questions to lay down definite principles which it is hoped will be accepted in the different countries represented on the International Association.

For the purpose of presenting the case of the English-speaking nations private conferences were held each morning preceding the Congress discussion and a common policy decided upon for Great Britain, the United States and Canada. Colonel C. H. Bressey, the chief engineer of the Roads Department of the Ministry of Transport, acted as the main spokesman at the meetings of the sections dealing with road construction and maintenance. The discussions were initiated by a series of provisional conclusions submitted by the French delegation, and the final form of the conclusions was established at the closing general meeting of the Congress, held on Saturday last.

The first subject taken for discussion was that of concrete road surfaces, the reports on which were summarised in our last issue, and although the final wording of the conclusions has not been determined at the time of writing, their general purpose may be stated. They are to the effect that concrete road surfacings of Portland cement properly executed are able to resist the heaviest traffic if the wheels of vehicles using the roads are provided with rubber tyres.

Reference was made to the fact that these roads are suitable for all climates, that the materials of construction are available in nearly every country, and that given certain conditions concrete roads when worn can serve as a foundation for other types of surfacing or be renewed with concrete. Dealing with details of construction, the conclusions state that the Portland cement used must be of the highest quality, that the fine aggregate should, if possible, be sand with certain limitations in size of grain, and that the utmost care must be taken to obtain the concrete in a compact form. Stress is also laid on need of a methodical study of the question of the water content. In general the executing of the surfacing in two layers is not recommended. No definite opinion is expressed as to the superiority, if any, of reinforced over ordinary concrete for road surfacing. It is suggested that the problem of cracking and the advantages claimed in some quarters for expansion joints should be the subject of research. Reference is also made to the fact that, independently of the concrete highway proper, reballasting with macadam, with which an aggregating mixture of sand and hydraulic binding is incorporated, has given interesting results. Slightly dearer than ordinary macadam with water, this mixture, completed by surface tarring and maintained by the use of tar or asphalt, is recommended for roads subjected only to average traffic, and for which for the time being there is no intention of using concrete. The objections to the concrete road were not overlooked. It is costly, calls for great care in construction, is a difficult material in which to open trenches, and repairs are rather difficult to effect.

BRITISH PRACTICE.

An animated discussion took place when the reports on bitumen and asphalt surfacing systems were brought up. The substance of these reports was given in last week's issue, and the provisional conclusions, which may be modified in detail, when they are finally approved, can be stated. The Congress put on record an expression of opinion that English and American experience has given two satisfactory forms of two-coat ashphalt and of asphaltic concrete, and that French experience has evolved a satisfactory form of one-coat surfacing. Operative methods, both with regard to the making and application of the mixture are, it is stated, now well ascertained, and the qualitative determination of the elements of the mixtures known. This is not the case with quantitative determination, which is a function of the climate and the traffic of the road. It is regarded as of particular importance to continue observations and researches on the effects obtained from varying the proportions of the materials for the aggregates and their relative sizes, it being, of course, understood that the mixtures should always be compact and present the fewest voids possible.

Other subjects dealt with at the meetings of the sections were the laying of tramway rails on various kinds of road surface, the development of motor transport, the problem of traffic on congested streets of towns and the desirability of framing in all countries uniform traffic regulations. On this last-named subject it is proposed to appoint an International Committee.

MECHANICAL APPLIANCES FOR ROADS.

What has been done during recent years to evolve improved mechanical appliances for road work was dealt with in several special reports, and a small exhibition of British and foreign plant was held in the grounds adjoining the Congress Hall. To this Messrs. Marshall, Sons and Co., and Messrs. Aveling and Porter, contributed respectively a 10 ton and 8 ton road roller with scarifier.

The report on English developments in machinery was prepared by Mr. Albert E. Brookes, chief engineer to the Durham County Council, and by Mr. Arthur E. Collins, the city engineer of Norwich, this report giving a brief account of the changes which have come about with the development of mechanically-propelled road traffic.

Machinery for the manufacture of tar macadam

may be either portable, for manufacture on the roadside, or fixed, for manufacture at a quarry, works or depot. Essential features in both types of machinery are efficient drying units which will ensure, not only that the aggregate is raised to the proper temperature, but also that all moisture is driven off. The most efficient method of drying is stated to be that of the heated floor, but as it is not mechanical it is far too slow and expensive for modern requirements.

For the treatment of cold blast slag for the manufacture of tar macadam at a fixed plant, Mr. Brookes has found that the double-cylinder type of dryer has given the most satisfactory results, both as regards solidity of construction and efficiency of operation.

This machine consists of two long concentric steel-plate cylinders set with the delivery-end slightly lower than the feed-end, the gases from the dryer furnace being taken down the central flue and then returned through the outer annular space, being finally exhausted to the atmosphere by a fan. On entering the inner flue the gases are reduced by the addition of excess air to a temperature of about 1,350 deg. F., and a great part of their heat is imparted to the inner shell, so that when they reach the outer shell they are at a temperature of 350 deg. F., while at exhaust they are reduced to 150 deg. F. The loss by radiation is therefore very small, since the outer shell is only in contact with cool gases and the loss at exhaust is reduced to a minimum.

The material is fed into the outer annular space at the furnace end of the dryer and is gradually worked to the delivery end, owing to the angle at which the dryer is set. The moisture evaporated is constantly carried away by the gases and the material while passing along its long spiral path through the dryer is continually raised in temperature until just before discharge it comes in contact with the dry gases at a temperature of 350 deg. F. The inner and outer shells are rigidly connected midway by six cast-iron braces. Between these and each end there are swinging braces which provide additional support and allow for the inevitable unequal expansion due to differences in temperature. This construction obviates stresses due to unequal heating, eliminating the shearing of rivets and loosening of joints. At the furnace end the inner cylinder extends through the stationary feed head and connects directly with the flue from the furnace. This inner shell forms an extended combustion chamber for the unconsumed gases leaving the furnace, and perfect combustion is claimed to be assured. These machines are capable of an output of 25 tons per hour.

New plants are now available for the production of road material on the site. Some are entirely self-contained, being mounted on road wheels and combining feeding, drying and mixing units. The power required for a plant having an output of 9 tons to 12 tons per hour is 24 b.h.p., and this is distributed through appropriate gearing to the elevator, drying unit and mixer. The fuel consumption, while varying according to the class of materials being dealt with, may be taken as approximately 1·9 cwt. of coke per hour, or 19 cwt. per ton of finished material produced. A modification of this plant has been made for the manufacture of asphalt carpeting material. This plant is essentially for use in producing asphalt, by which is meant sand, bitumen and filler. It comprises two units both of which may be portable or stationary, one of which is concerned with the drying process and the second with the measuring and mixing processes.

Mr. Collins referred to the "Aero" concrete mixer. In this, he said, an entirely new principle as applied to concrete mixing is embodied in that the cement is blown on to the damp aggregate as a cloud of dry cement instead of the usual dry mixing followed by wet mixing being adopted. The particles of aggregate are separated before falling through this cloud to ensure access of the cement on all sides of each. The application of this principle in Mr. Collins' experience enables equally good concrete to be made with less cement than by any other method now practised or, of course, better concrete with equal quantities of cement. The latest type of this machine has a capacity of from 4 tons to 6 tons per hour. It is self-propelling on a caterpillar track. A turntable intervenes between the chassis and the machine proper, and this, in conjunction with turntable mounted delivery chute, gives opportunity for the rapid delivery of concrete over a large area of surface without moving the machine. It is built for the easy on and off loading of railway trucks without extensive dismantling.

Since the date of the last Congress there has been a considerable advance in the use of loading machines for road work. They do not supersede storage hoppers, but are more useful, being capable of travelling under their own power. One machine used at Norwich will load road shingle from a pile into a cart or motor wagon at the rate of about a ton a minute from the time it starts. Allowing for manœuvring of vehicle to and from machine from 5 minutes to 8 minutes are occupied in filling a 1-ton cart and about 12 minutes to 15 minutes by a 4-ton motor wagon.

The machine consists essentially of a steel frame on road wheels carrying a petrol engine and an adjustable chain and bucket elevator which discharges into a turntable chute which provides for considerable latitude in the positioning of the vehicle to be filled. The engine drives the road wheels as desired and can be operated by one attendant. Under very favourable conditions one of these machines will deal with 80 tons per 8-hour day, and a quite normal figure is 50 tons.

The most important general change in transport methods during recent years has, it is pointed out, been the almost universal adoption of the steam or petrol rubber-tired vehicle, which has almost entirely displaced the tractor and steel-tired vehicles of former years.

The report from the United States is a compilation by 10 authorities, including highway engineers, consulting engineers and highway commissioners. It covers a very wide field, and reference need only be made to some of the dominant features of recent developments.

There has been a marked increase during and since the war period in the use of mechanical road material loaders of either the bucket and endless chain or belt elevator type. Developments in the first type consist of serrated or toothed loading edges for the buckets and of automatic feeding devices at the loading end. Many loaders are now mounted on caterpillar traction and can be moved under their own power. A newer machine is a combination bucket and belt loader. The buckets dig and lift material a few feet and deposit it on an endless belt, which conveys it to vehicle, storage bin or mixer. Recognising that the cost of road building depends in large measure upon the methods adopted for transporting the raw materials of construction, special attention has been given to the reduction of handling costs by the development of narrow-gauge industrial railways.

The common gauge of these lines is 24 in., and they are laid with 15-lb. to 25-lb. rails. The most satisfactory size of locomotive is the 6-ton, and gasoline engines are now displacing the coal-fired steam locomotive. It is stated to be possible to convey materials on these railways at a cost of 7½ cents per ton-mile. New developments in this field are predicted. Until recently the cars consisted of a single truck of four wheels with axles supporting a steel frame on which rested the V-body used for grading work or the batch bodies employed for conveying the proper proportions of raw ingredients for a batch of concrete. In some cases the cars are equipped with two box bodies, and recently experiments have been made with five bodies mounted on the same truck.

For road excavation work an increasing use is being made of small hammer rock drills, and small compressed air machines. The all-hammer drill has, of course, been evolved from the pneumatic riveter. The augur drill, the bit of which cuts the rock like an ordinary hammered bit, but removes the chips, is a recent development. For deep drill holes in road excavation the old percussion type of drill remains the favourite tool, but much improvement has been made in the details of design and in the quality of the materials used in construction. Greater toughness has been secured by the use of special ferrous alloys.

The mechanical loading of blasted rock still remains an economic problem that has not been satisfactorily solved where the cut is shallow and the rock in large chunks. Only a small daily yardage can be loaded at best with a steam shovel where the cut is shallow; and the bucket of the typical small shovel will not load the large chunks of rock. However, this difficulty may be reduced by the use of rock tongs that are placed by hand on each rock, which is then lifted by the steam shovel.

Reference is made in the report to the great improvements which have been effected in rock and gravel-crushing and screening plants. The almost universal use in large plants of the steam shovel with track or caterpillar traction in loading cars in the pits and quarries is the subject of comment. It is regarded as an important advance in the handling of stone and gravel. The cable line and dipper is still the most common way of taking gravel from water in land plants. The front continuous dump dipper is a recent development. It has a decided advantage over the rear dump dipper which, it is said, takes time in closing and sometimes fails to close.

The pumping of gravel from deposits not too highly cemented together is used extensively, and the water for use in cleaning and sorting is carried along with the gravel.

Clean stone and gravel aggregate of small size, free from dust, a great amount of which is used in bituminous and cement concrete work, is produced in dry plants by the use of the shaker or vibrator screen which is coming into use quite rapidly. The screens are vibrated by a cam or by a tapping vibrator operated by electricity. These screens make it easy to remove the dust from limestone.

The distribution of bituminous material by hand pouring and by machines with a gravity flow has been largely abandoned in favour of machines working under pressure.

The greatest development in distributors since the last congress has taken place in the motor truck type. Many of the large asphalt and tar companies maintain a fleet of such trucks to distribute their materials from central supply stations. Material is hauled in these trucks and applied on work sometimes as much as 50 miles away from the central plant. A large part of the material used for road oiling, surface treatments and for penetration work is now applied by motor truck distributors. Motor truck distributors are made with tanks of from 800 gallons to 1,000 gallons capacity. It is possible with most makes to fill the tank of the distributor from tank cars by the equipment which develops the pressure so that an additional pump for this purpose is not always required.

NOTES.

PRESENTATION OF THE FARADAY MEDAL TO SIR CHARLES PARSONS.

The Faraday Medal of the Institution of Electrical Engineers has as yet a short history, but the council of that body may be congratulated on the fact that it has made that history a very distinguished one. There is much to be said for the institution of an award of this kind which enables a professional body specially to honour individuals who are eminent in the profession which it represents. The higher the standard set by the institution awarding the medal the greater the honour conveyed by it, and if the Institution of Electrical Engineers can maintain in the future the standard it has so far set its Faraday Medal may well become one of the most prized awards in the scientific world. The first medal was presented to Mr. Oliver Heaviside last year and his name is worthily followed by that of Sir Charles Parsons, to whom the second award of the medal was made at the meeting of the institution on the 10th inst. and prior to the delivery of the fourteenth Kelvin Lecture by Dr. J. A. Fleming. A very large audience gathered for the ceremony, and all the important engineering and allied institutions were represented by their president or vice-president. Sir Charles may certainly be said to be the most distinguished living engineer, and it was a pleasure to see the tribute paid to him by the large and distinguished audience. The medal was handed to Sir Charles by Mr. Frank Gill, the President of the

Institution, and previous to the presentation brief speeches were made by Mr. J. S. Highfield and Dr. Ferranti. Mr. Highfield referred to the power possessed by Sir Charles Parsons of seeing things as they are and not as we are told they are. This preception, akin to the curiosity of childhood, was an essential mark of genius and had enabled Sir Charles to get away from the idea that steam was merely something exerting pressure and to conceive of it as something in motion. This idea had led to the steam turbine, but wonderful application and determined constancy of purpose had been necessary to carry the idea to the conclusion represented by the great machines of to-day. Dr. Ferranti dwelt on the peculiar debt which electrical engineers owed to Sir Charles. The steam turbine stood behind all the great electrical developments of the day and without it many of them would not have been possible. After the receipt of the medal Sir Charles, in expressing thanks, referred to the work of Faraday, whose life should always be an inspiration to the workers who followed him.

The International Navigation Congress.

International congresses on such matters as roads, railways and shipping undoubtedly do much good in bringing the technical and administrative ideas of various countries to the attention of workers and officials generally. Railways and railway matters were dealt with at the congress held in Rome last year, while roads were discussed at the congress which assembled at Seville on the 7th inst. and of which we conclude our report of the proceedings in our present issue. The questions of ships and shipping are to have their turn on July 2 next when the International Navigation Congress opens in London. The meeting is the thirteenth promoted by the Permanent International Association of Navigation Congresses. The President of the congress is the Right Hon. Lord Desborough, and the meeting will be held in the building of the Institution of Civil Engineers. The congress will be divided into two sections, one dealing with inland navigation and the other with ocean navigation, and there should be much in the proceedings of both sections to interest engineers. The first question to be dealt with by the inland navigation sections is a purely engineering one, being "The Utilisation of Waterways for the Production of Power." This question will be covered by reports from Czecho-Slovakia, France, Great Britain, Italy, Sweden and the United States. The report from Great Britain has been compiled by Mr. W. J. E. Binnie, Mr. C. S. Meik, Mr. J. W. Twinberrow, Mr. G. L. Addenbrooke and Mr. R. F. Hindmarsh, so that a valuable contribution to what is a somewhat difficult subject should certainly be expected. It is not possible to reproduce the whole of the programme here, still less the names of all those who have been concerned in the preparation of reports, but the instance we have quoted will show that considerable importance must be allowed to the congress. Among the other questions which will be dealt with are "The influence of surface waters and subterranean sheets of water on the flow of rivers"; "The accommodation to be provided for ships in connection with the construction of new works at ports in order to satisfy the future dimensions of ships"; "The relative advantages of ship equipment and port equipment for loading and discharging ships"; "The use of liquid fuel," and other matters, many of much general interest. The meeting will continue for a week, and during the week following visits will be paid to Southampton, Manchester, Liverpool, Bristol and other ports.

The Development of the Steam Turbine.

In the third and concluding Howard lecture on "The Development of the Steam Turbine," delivered at the Royal Society of Arts on Monday, the 14th inst., the lecturer, Mr. Stanley S. Cook, B.A., dealt mainly with the application of gearing to land turbine installations. The use of gearing, he said, resulted in an improvement in efficiency and a reduction in the size of the plant, and also served to extend the field of usefulness of the turbine. For driving alternators, gearing helped to accommodate the turbine speed to the conditions imposed by the supply frequency, and it also simplified the problem of commutation when direct-current generators were required. The lecturer illustrated a number of geared turbo-generators, a rolling-mill plant driven by geared turbines, and also showed the same form of prime mover applied to the operation of textile mills and paper mills by means of rope drives. He dealt briefly with the "pass-out" turbine used when low-pressure steam is required for heating and process work, and subsequently explained that while the geared turbine found numerous applications on land it had by no means ousted the direct-coupled machine for stationary work. Direct-coupled machines, he said, were used for driving rotary blowers and compressors, but their greatest field of usefulness was for the generation of electric power. Dealing with the development in the size of units, the lecturer remarked that twenty-five years ago a 1,250 k.v.a. turbo-generator running at 1,500 r.p.m. was regarded as a large machine, but a single unit was now under construction which would develop 40,000 k.v.a at 1,800 r.p.m. The lecturer then referred to the changes in alternator design necessitated by the high speed of the steam turbine, and afterwards dealt with the ventilation of large turbo-generators. He pointed out the advantages of the closed system of ventilation, in which the same quantity of air is continuously circulated through the machine and cooled by tubular coolers, mentioning that no dust collectors or filters were necessary with this system while the danger from fire was reduced owing to the fact that only a limited supply of air was available to support combustion. The last part of the lecture was devoted to a brief explanation of the thermodynamic principles of the steam turbine which the author gave with the aid of a temperature-entropy diagram. He referred to the possibilities of feed heating on the cascade system and mentioned that, theoretically, an increase of 13 per cent. in efficiency was possible by this means, while by heating the feed in three stages a gain of 8 per cent. in efficiency could be obtained in practice. The effects of superheating and reheating were also discussed, and the lecturer concluded by stating that steam turbines of 100,000 k.v.a. capacity, and working with an overall thermodynamic efficiency of 28 per cent., were now within the range of possibility. He added that the attention of boiler makers could profitably be directed to the possibility of raising steam pressures and temperatures still higher than had been done up to the present.

The Air Ministry Competition for Helicopters.

As already announced, prizes to the total value of 50,000*l.* are to be awarded by the Air Ministry for the successful completion of certain flying tests applicable to helicopters or equivalent types of flying machines, and particulars of the conditions to be complied with in these tests have now been issued. The machines will be required to carry a pilot, fuel for one hour's flight, and 150 lb. of military load, and thus loaded the machine must make a vertical flight from the ground to a height of 2,000 ft., afterwards descending and landing without damage; two wind conditions are specified for this test, one in which the ground wind does not exceed 5 m.p.h. and the other in which the ground wind exceeds 10 m.p.h. but does not exceed 20 m.p.h. In another test, the machine will be required to rise from the ground and remain in the air at 2,000 ft. for half an hour over a certain prescribed ground area, the ground wind being not less than 5 m.p.h. and not exceeding 20 m.p.h.; the subsequent landing must be made without damage. The conditions for a third test are similar, except that, in this case, the machine must fly over a prescribed closed circuit not less than 20 miles in length and at an air speed of 60 m.p.h. or over, while in a fourth test the machine must be manœuvred in the air into a position over a given point on the ground and must descend from a height of not less than 500 ft. with the engine off, alighting without damage within 100 ft. of the given point. A prize of 5,000*l.* will be awarded in connection with the first-mentioned test and additional sums of 15,000*l.*, 20,000*l.* and 10,000*l.*, respectively, will be awarded in respect of the other three tests. More complete particulars of the conditions to be complied with can, of course, be obtained from the Secretary, The Air Ministry, Adastral House, Kingsway, London, W.C.2, but we should mention that the entries, which are not confined to British subjects, must be received by the Air Ministry on or before April 30, 1924. We also note that no part of the prizes above referred to will be awarded in respect of the Brennan helicopter now under construction for the Air Ministry. In conclusion, we may remark that while a machine capable of complying with all the test conditions outlined above would certainly be a very distinct advance on any helicopter at present in existence, its performance, in our opinion, would still leave much to be desired in a machine to be used in actual warfare. Presumably, however, the Air Council are fully conversant with military requirements in this direction and are convinced that a machine capable of giving the specified performance would be of real service to the nation and that it would lead to the production of such a machine; otherwise it is hardly conceivable that the prizes would have been offered. It, of course, remains to be seen whether any entries will be forthcoming and whether the machines entered will be successful, but we understand that any of the prizes not awarded will again be offered for competition within a further period of one year dating from the announcement of the result of the original tests.

TULLY GAS PLANTS.

Most gas engineers, we presume, are familiar with the Tully process of making an enriched water gas from green coal, since upwards of 200 plants of this type are now in use in this country and abroad. For those unacquainted with the process, however, we may explain that it was developed jointly by Mr. C. B. Tully and the late Professor V. B. Lewes, the first plant produced some twenty years ago being similar to but an improvement on the Dellwick water-gas plant. We understand that one of the first Tully plants supplied is still in operation at the Swindon works of the Great Western Railway Company.

As now made, a Tully plant comprises a producer similar in form to, but about 50 per cent. larger than, a water-gas producer of the same capacity. Above the producer and in direct communication with it, however, is a conical vertical retort surrounded by chequer brickwork and into the top of this retort green coal, or a mixture of coal and coke, is fed at intervals. In general, the method of working the plant is similar to that used with an ordinary water-gas plant, *i.e.*, air under pressure is passed through the fire for a short period to promote combustion, after which gas is made by passing steam through the burning fuel. The special feature of the Tully plant is that the heat of the blow period, which is normally wasted, is utilised partly to carbonise the green coal and partly to superheat the steam used in gasmaking.

During the blow period, the air passed through the fire is directed up through the chequer work surrounding the retort, secondary air being admitted at the base of the chequer work to support combustion of the gases in the latter. The chequer work is heated to a high temperature in this way and the small part of the heat which is conducted to the coal in the retort assists in the carbonisation of the fuel. In the process of gasmaking, steam is first admitted below the fire and the hot gas produced passes up through the coal in the retort, leaving through an outlet at the top. The effect of this is, of course, to heat and carbonise the coal so that the latter, as it descends, reaches the fire zone of the producer in the form of coke. At the same time, the volatile constituents of the coal are taken up by the hot water gas and the quality of the latter is materially improved. In the last stage of gasmaking, steam is admitted at the top of the chequer work and is superheated in passing down through the latter on its way to the producer This has the effect of restoring to the system part of the heat that would otherwise be lost during the blow period, and also enables the period of gasmaking to be extended. At Bedford Gasworks, where we have recently seen one of these plants in operation,

the blow period occupies two minutes, while gas-making proceeds for five minutes (four minutes upward flow and one minute downward flow).

The gas produced in this way has a calorific value of about 350 B.Th.U. per cubic foot, and it contains, roughly, 48 per cent. of hydrogen, 32 per cent. of carbon monoxide, with 10 per cent. each of methane and inerts. After being scrubbed and purified, the gas can be used for industrial and domestic heating and for lighting by means of incandescent mantles. In most cases, however, it is mixed in suitable proportions with "straight" coal gas from ordinary retorts, and by this means a gas of higher calorific value and lower carbon-monoxide content than Tully gas is obtained; this is the procedure adopted at Bedford.

Recently, however, Messrs. Tully Gas Plants, Limited, of Newark-on-Trent, have been making some experiments on the elimination of carbon monoxide from town gas or Tully gas, and of otherwise varying the composition of the latter to cover a wide range of industrial requirements. Catalytic reactions are, of course, employed for the purpose, and we are informed that the practical difficulties frequently experienced with these reactions have been overcome, although we have not seen the plant in operation. For the elimination of carbon monoxide, the gas is heated in the presence of steam to a temperature of from 400 deg. to 600 deg. C., the temperature necessary depending upon the particular catalyst used. The carbon monoxide and steam are thereby converted into carbon dioxide and hydrogen in accordance with the formula $CO+H_2O=CO_2+H_2$. The carbon dioxide can be absorbed by water, or by other means, and a gas containing about 85 per cent. of hydrogen can thus be obtained. Such a gas would be useful for ammonia manufacture and for other synthetic industrial processes, and the total cost of producing it from coal at 30*s.* per ton, we are informed, would amount to about 1*s.* 6*d.* per 1,000 cub. ft. Moreover, in the case of a hydrogen-rich gas, any carbon monoxide present can be converted into methane and water in the presence of a nickel catalyst at a temperature of 300 deg. C. This process, for which the formula is $CO + 3H_2 = CH_4 + H_2O$, would enable a gas of low carbon-monoxide content, and consisting mainly of methane and hydrogen in roughly equal proportions, to be produced. This gas could be mixed with straight gas to obtain a town supply having a calorific value of about 500 B.Th.U. per cubic foot, and the cost of manufacturing the final product, we are informed, would be well below that of ordinary town gas.

There are, however, many possible industrial applications of Tully gas of normal composition, and one of the more recent of these is in connection with the low-temperature carbonisation process of manufacturing smokeless fuel and recovering by-products. For this work, the Tully gas can be used both for heating the retorts for the carbonisation process and for diluting the rich gas, having a calorific value of from 700 B.Th.U. to 1,000 B.Th.U. per cubic foot, produced in the retorts. For developing this particular application, we understand that Messrs. Tully are about to amalgamate with Messrs. Low-Temperature Carbonisation, Limited, whose plant at Barnsley was fully described on page 596 of our issue of October 28, 1921. Several Tully gas plants have been supplied for industrial heating work, one of the most recent installations, capable of producing 600,000 cub. ft. a day, having been supplied to a Swiss glass works. For such work, Tully gas has the obvious advantage over producer gas that the higher calorific value of the former enables smaller mains to be used for the supply of the gas and the capital cost of the whole installation is thereby reduced; higher efficiency and lower first cost are also claimed for the Tully plant.

In conclusion, we may perhaps attempt to correct the impression created by some statements in the daily press as to the supply of town gas from which carbon monoxide has been almost completely eliminated. If we understand the position correctly, it is not proposed to reduce the proportion of carbon monoxide in the gas below that of from 7 per cent. to 10 per cent., which has been supplied for many years without any deleterious effects. Carbon monoxide is, of course, a valuable constituent of the gas from the thermal point of view, and the only reason for replacing it with hydrogen or methane would be to allay the apprehensions of the public as to the toxic properties of the former. Any very slight risk there may be in this direction, however, arises mainly from defective fittings, and these are a possible source of trouble in any case, quite apart from the proportion of carbon monoxide in the gas. Gas leakage can always be detected readily enough by the sense of smell, since, although pure carbon monoxide may be odourless, the other constituents of town gas are quite sufficiently pungent to give olfactory evidence of their presence even in extremely small quantities.

INDUSTRIAL NOTES.

THE outstanding feature to remark upon this week is the delay taken by the Boilermakers' Society in making known the result of their members' ballot on the question of the endorsement or non-endorsement of the recommendation of the national conference, held in London, on April 24. There voted for endorsement 14,565, and against 4,475, the figures showing that a majority of 10,090 refuse to accept the overtime and night shift agreement. The men who voted numbered, as will be seen, 19,040 only. The total membership of the society, according to the ninety-fourth quarterly report recently issued by the General Federation of Trade Unions, is 92,073, whilst the membership on which contributions are paid is given as 76,815. An estimate places the number of men affected in the particular case at 20,000, and satisfaction is found in some quarters in a comparison between the ballot total and this latter figure. But on the other hand, another statement is to the effect that the votes are taken at meetings of the branches, and insufficient notice was given for halls to be engaged for the purpose, this explaining why returns had not been received from many branches. That one of the country's staple industries should be allowed to become totally disorganised as a result of such apathy and pretences are painful in the extreme.

Mr. W. Adamson brought in a Bill in Parliament last week to amend the Coal Mines (Minimum Wage) Act, 1912, the object of which "was to secure to every workman in and about mines a minimum wage equal to the increased cost of living to-day, as compared with the cost of living on August 4, 1914." He stated that against a pre-war average wage of 6*s.* 5*d.* per day, the earnings now were only 9*s.* 6*d.*, an increase of about 45 per cent., lower than the increased cost of living. In regard to this Bill, the Mining Association say that, assuming 6*s.* 5*d.* to be the correct average pre-war wage, it was certainly not the fact that 9*s.* 6*d.* represented the present average earnings, although this figure was officially given as the average for the last quarter of 1922. Wages had since risen, and showed a pronounced tendency to rise still higher. They stood at 9*s.* 8·7*d.*, or an increase of 49·2 per cent. in January and February, whilst it was estimated that current earnings, which were based upon the working results of January-February, averaged over 9*s.* 10*d.* per shift, equivalent, therefore, to an increase of 53 per cent. above the pre-war level. It was expected that the next ascertainment would show a considerable increase over the latter figure.

The modified proposals made by the railway companies in regard to further cuts in the balance of the war bonus still being paid to the railway shopmen are to be balloted upon. The results of the ballot are expected to be known on the 26th inst.

In the quarterly report of the General Federation of Trade Unions, to which reference is made above, the secretary, Mr. W. A. Appleton, says that the saddest phase of the trade unionist's experience is that connected with falling funds and falling membership. He adds that every sane man actually in the movement knew quite well that war-time conditions could not continue for ever, and that membership would fall when men and women were no longer compelled, as a condition of employment, to join some trade union. The most pessimistic, however, hardly felt that the lapses would be so sudden and so severe. Many of those who came in during war-time were influenced less by conviction than by the narrower type of self-interest. Some unions have had to do what banks do when they incur liabilities beyond their capacity; they have had to suspend payment. Financially, Mr. Appleton adds, the General Federation has much to be thankful for. It has, apart from overpaid benefit which is to be repaid, unhypothecated and rapidly realisable assets of 94,000*l.*, and it has met every call from its affiliated unions. The membership on which contributions are paid is 967,897, the total membership being 1,056,131. We believe Mr. Appleton's remark as to membership of a union being no longer compulsory is open to criticism.

Mr. Hugh Fraser, the arbitrator between the National Allied Building Trades Employers and the National Allied Building Trades Operatives, issued his award in the matters in dispute between the two bodies. He found that the agreement mentioned in the reference to arbitration as the National Wages and Conditions Council document required revision by mutual consent in the interests of the entire industry, and with a view to the purposes and intentions of the parties thereto being more clearly indicated. He awarded and directed that such revision be made at or before the statutory meeting in January, 1924. In the meantime, with the object of securing peace in the industry and stability as to wages and conditions of employment, he awarded and directed that alterations be made forthwith in the document. Among these alterations is one to the effect that on and from Saturday, the 26th inst., and down to the date of the statutory meeting in January next, grades A craftsmen (with the exception of London) and grades B craftsmen, shall be reduced by 1*d.* per hour; London area craftsmen shall be reduced ½*d.* per hour; grades C craftsmen shall be reduced ½*d.* per hour; labourers wages shall be maintained as near as possible at 75 per cent. of the craftsmen's wages. These reductions to be on account of future adjustments rendered necessary by the cost of living sliding scale. This scale is to be taken as a basis in the future.

Sir George B. Hunter, chairman of Messrs. Swan, Hunter and Wigham Richardson, Limited, Wallsend, stated a few days ago that the orders for a floating dock for South America, and for another for the Continent, both of which his firm hoped to secure, had been placed with Continental firms who had quoted lower prices.

The last issue of the quarterly journal published by the British Chamber of Commerce in Belgium (Incorporated) states that the aftermath of the war has left the world with a large population more or less devoid of the old-fashioned virtues of hard work, thrift and a desire to do their part honestly and well. No scheme, however carefully planned, can right the world which does not take into account that salvation must come from within. Only the people can save themselves. Other clouds, of course, obscure the horizon also, amongst which reparation payments and international debts stand out prominently. These latter are closely allied with another factor of transcendent importance—the wire-pulling and financial influences at work below the surface, from which the wisest and greatest statesmen cannot shake themselves wholly free. Of these influences, the public, even the more enlightened section of it, know so little that it is well-nigh impossible to get at real facts.

Speaking on the 10th inst. before the Association of Trade Protection Societies of the United Kingdom, at their seventy-fifth annual meeting, Sir Eric Geddes gave a comparison between British and foreign labour costs. For identical administration, machinery, control and quality all-round, the ratio in direct wages cost was in Germany 2, in France 4, and in Great Britain 6. It might be thought that this was due to the increased efficiency of the German and French workmen, but that was not the case. It was a satisfaction, though in this case rather a sad satisfaction, to know that, whilst it was impossible to generalise, the British comparative efficiency was higher than the German or the French, otherwise the discrepancy would be very much greater. Sir Eric Geddes added that the countries having a depreciated currency were able—because of their labour rates and owing to their cost of living not having kept pace with the depreciation in their currency—to export to countries like our own, having a good currency, at costs with which the British workman, even with his higher efficiency, was unable to compete. The statement by Sir Eric Geddes with reference to the present cost of living compared with pre-war costs in countries having a depreciated currency is likely to be disputed by the inhabitants of some of those countries.

The mental influence of the trade union system upon the youth of a country usually receives little consideration, says *The Iron Age*, New York. The unions may be very serious, but they have been joked about from time immemorial. Boys as well as men hear of the things "the union" does not allow and how it strives to make the member a unit, not an individual. He is "one carpenter," or "one bricklayer"; not a good worker striving to get on in the world by doing the best he can for himself and his employer. For what he is and what he gets he must thank the union, not himself. The last thought of a boy is that of getting a job in which somebody will take care of him. He will take

care of himself, and what he looks forward to is getting into the field in which he will have the biggest and broadest opportunity. The callings in which there are unions are precisely those that do not offer any such prospect.

STEAM HYDRAULIC STAVING PRESS.

THE applications of hydraulic pressures in workshop processes, where heavy loads are essential, is productive of economical and rapid working. In the issue of ENGINEERING, of March 16 last, two hydraulic machines, built by Messrs. Fielding and Platt, Limited, of Gloucester, were described, the one being designed for shearing plates and the other for wheel pressing.

The illustration annexed shows a hydraulic plant constructed by the same firm designed for staving purposes and useful in such processes as jumping up crankshaft ends, tube staving and work of a similar character. This machine is provided with two separate hydraulic cylinders mounted on a heavy box-section, cast-iron, bedplate. The ram of the vertical cylinder which is used to grip the work between the dies, can move through 12 in. and is of sufficient size to transmit a total force of 150 tons. Steel upright columns fitting into the base, support the vertical cylinder and its equipment by means of heavy nuts. The actual staving operation is performed by the ram of the horizontal cylinder, which is made of Siemens cast steel, and is bolted to the bedplate.

This machine is operated on the steam-hydraulic system and is thus completely independent of any outside hydraulic supply. Direct-acting steam cylinders are employed to effect the return strokes. Water-saving arrangements are introduced by having an overhead tank supply and applying the pressure only at such times as are requisite to carry out the work. The steam driver has the steam hydraulic cylinder provided with outside hemp-packed glands and can give a stroke on the horizontal staving ram of 6 in., and a stroke of 9 in. on the vertical ram when required. In the machine illustrated the steam pressure available is 120 lb. per square inch, but similar plants may be constructed to work with any available steam pressure, or to operate on the pure hydraulic system, taking supply from any available hydraulic mains.

ROTATING DISCS OF CONICAL PROFILE: ERRATUM.—Mr. Hodgkinson, of the Metropolitan-Vickers Company, Limited, Trafford Park, Manchester, has called attention to an error in equation (9) on page 2 of our issue of January 5, 1923, where $\left(3 - \frac{1}{m}\right)$ should read $\left(3 + \frac{1}{m}\right)$, so that the correct form of equation (9) is

$$\left(1 - \frac{1}{m}\right) P + (3 - 2x)\frac{dP}{dx} + x(1-x)\frac{d^2P}{dx^2} + \left(3 + \frac{1}{m}\right) T x (1-x)^2 = 0.$$

As a consequence, the values for p_e, given in Table II, page 115, of our issue of January 26, 1923, should all be multiplied by $\frac{3 \cdot 3}{2 \cdot 7}$, and a corresponding correction is required in the values given for q_e. These corrections have been made in the reprint of the table given below:—

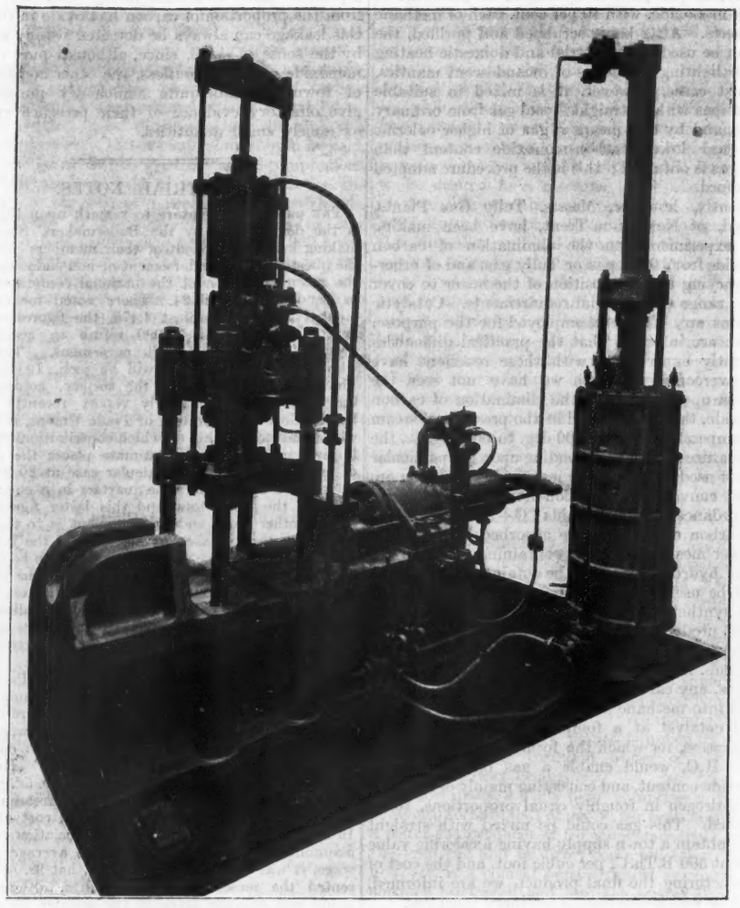
TABLE II.—*Stresses Developed in Complete Double-Conical Disc by different Methods of Loading.*

—	Stresses due to Centrifugal Forces, Lb. per sq. in.		Stresses due to a Pull of 1 Lb. per Inch Run Applied to Knife-Edge Forming Periphery of Complete Disc Lb. per Sq. In.		Stress Coefficients due to an Infinite Pressure Applied to the Interior of an Infinitely Small Hole Drilled Through Centre of Disc.	
$x = \frac{r}{R}$	Radial $p_e = T^* \times$	Tangential q_e $T^* \times$	Radial p_1	Tangential q_1	Radial p_2	Tangential q_2
0·0	0·1655	0·1655	1·435	1·435	∞	∞
0·05	0·1709	0·1695	1·497	1·475	−273·4	288·6
0·10	0·1753	0·1727	1·559	1·518	− 66·62	77·28
0·15	0·1782	0·1752	1·627	1·565	− 28·68	36·55
0·20	0·1794	0·1768	1·707	1·617	− 15·54	21·91
0·25	0·1785	0·1773	1·796	1·674	−9·553	14·88
0·30	0·1761	0·1768	1·898	1·738	−6·371	10·89
0·35	0·1734	0·1758	2·015	1·809	−4·387	8·531
0·40	0·1694	0·1739	2·151	1·890	−3·158	6·915
0·45	0·1635	0·1712	2·311	1·983	−2·328	5·788
0·50	0·1560	0·1676	2·501	2·090	−1·743	4·944
0·55	0·1466	0·1631	2·733	2·217	−1·309	4·301
0·60	0·1355	0·1580	3·021	2·369	−0·9988	3·816
0·65	0·1230	0·1520	3·390	2·556	−0·7523	3·419
0·70	0·1094	0·1451	3·860	2·794	−0·5670	3·102
0·75	0·09558	0·1371	4·559	3·111	−0·4161	2·835
0·80	0·08055	0·1285	5·563	3·557	−0·2971	2·614
0·85	0·06336	0·1189	7·263	4·276	−0·1995	2·421
0·90	0·04425	0·1090	10·620	5·554	−0·1205	2·263
0·95	0·02315	0·0977	20·845	8·890	−0·0555	2·140
1·00	0·00000	0·0893	∞	∞	0	2·051

* $T = 2\left(\frac{D}{10}\right)^2\left(\frac{R.P.M.}{100}\right)^2$ where D = external diameter of complete disc. (See Fig. 3, page 1 *ante*.)

STEAM-HYDRAULIC STAVING PRESS.

CONSTRUCTED BY MESSRS. FIELDING AND PLATT, LIMITED, GLOUCESTER.



LOCKWOOD'S PRICE BOOK, 1923.—The full title of this useful publication is "Lockwood's Builder's, Architect's, Contractor's and Engineer's Price Book." It is edited by Mr. J. P. Allen, and is issued at the price of 7*s.* 6*d.* net, by Messrs. Crosby Lockwood and Son, 7, Stationers' Hall-court, Ludgate Hill, E.C. 4. It covers house-building, from the digging of the foundations to completion in every respect, the cost of every single operation being given for labour and materials. The book contains very many tables of cost and prices, and of information on the subjects with which it deals, and interesting particulars on every trade and occupation connected with house-building, sanitation and so forth. Separate chapters cover the Building Acts, requirements, bye-laws, &c., all of which information is very carefully indexed.

THE DECAY OF BUILDING STONES IN ANCIENT STRUCTURES.—It has been decided to set up under the Department of Scientific and Industrial Research a special Committee of the Building Research Board to report on the best methods by which decay in building stones, especially in ancient structures, may be prevented or arrested. The chairman of the committee will be Sir Aston Webb, K.C.V.O., P.R.A., and the other members will be Mr. R. J. Allison, C.B.E., F.R.I.B.A.; Professor C. H. Desch, F.R.S.; Mr. A. W. Heasman, O.B.E.; Mr. J. A. Howe, O.B.E.; Sir Herbert Jackson, K.B.E., F.R.S.; Dr. Alexander Scott, F.R.S.; Mr. H. O. Weller, M.Inst.C.E., Hon. A.R.I.B.A. All communications should be addressed to the Secretary, Department of Scientific and Industrial Research, 16, Old Queen-street, S.W. 1.

RHINE REGULARISATION AT DIEPOLDSAU, SWITZERLAND.—One of the last stages of the regularisation of the Rhine between the Canton of St. Gallen, on the left bank, and Austria on the right, part of the great scheme which was adopted nearly thirty years ago, was commenced last month by blowing up the temporary dam at Diepoldsau, erected to separate the old bed of the Rhine from the new bed excavated to lower level, into which the river was deflected. The dam had a length of about 600 m., and at the crown a width of about 8 m. Hollow square piles, about 15 cm. (6 in.) side length, were driven down into the dam to a depth of 2·5 m. (8 ft.) below the level of the Rhine bed, there being three of these piles in each of the nine rows across the dam. At the bottom of a pile a charge of up to 16 kg. of trotyl was placed, this explosive being selected because it is little affected by moisture; the holes were tamped with damp sand. All the 29 mines were exploded (by electricity) at the same moment. Though the trotyl proved sufficiently strong to break up the mattresses of brush wood which had been placed on the river side of the dam, the Rhine level had sunk by 0·75 m. (2½ ft.) within the three days that elapsed between the laying of the mines and the explosion, and the rush of the water through the gaps created by the explosion was not so powerful as had been expected. But the Rhine will itself soon finish the work. A strong dam had been erected, because sudden thaws in the mountains and Rhine floods had always be feared.

UTILISATION OF WASTE ROCK IN LIME KILNS.—For the manufacture of quick lime various types of shaft kilns, working with natural or with forced draught, are used in the United States. Stones of less than 4 in. dimensions are mostly discarded because they interfere with the draught and lead to imperfect calcination. There is thus considerable waste of rock, and this waste is increasing at present, since stopes are being driven into the walls of the open quarries, and the underground pits give more smalls than open quarries. The United States Bureau of Mines is therefore inquiring (Reports of Investigation, No. 2,463, by Oliver Bowles) into means of preventing and utilising the waste of limestone. Rotary kilns, of the Portland cement type, are expensive, and the heat losses arising in lime burning in such kilns are said to be high. Yet rotary kilns are profitably combined in large plants with Mount shaft kilns, which themselves take stones in sizes down to 3 in., and with ordinary kilns. In small plants other uses must be found for the small stones too difficult to calcine. Smelters and blast furnaces will take some small stones for linings and for fluxing, but they generally have their own quarries. The uses of stones as road metal and as ballast for permanent way are locally restricted by transport charges. More could, however, be done in crushing and pulverising the limestone to serve as aggregate for concrete, as chips for facing concrete blocks, as substitute for sand in plaster and as fillers for fertilisers and for asphalt.

THE CERAMIC SOCIETY.

(Concluded from page 583.)

CONCLUDING our report of the spring meeting of the Refractory Materials Section of the Ceramic Society, held at Bournemouth on May 3 and 4, we may next refer to the paper by Mr. W. C. Hancock, B.A., entitled "*Note on the Abrasion of Fireclay Materials.*" Attention is confined to the simple rubbing away of a surface, erosion by impingement of a stream of particles (as fuel ash) not being considered. In the methods hitherto used for determination of abrasion, the abrasion was caused rather by grinding by direct rubbing. A different method of testing was therefore devised, the advantages claimed for it being that the wear is caused by actual abrasion, and not by grinding or scouring, that by loading the moving arm the pressure of abrading surfaces can be increased, that the abrading action of different materials on the test-piece can be determined by substituting various materials for the upper (moving) abrading surface, and that by placing the machine in such a position that the fixed and moving test-pieces are within a furnace, the abrading action at high temperatures can actually be determined.

The results of a few preliminary experiments lasting 1 hour, 3 hours, 8 hours, or 18 hours respectively, showed that when the two test-pieces are of the same composition (as in two pairs of bricks) the amount of abrasion is practically the same for each.

Tests lasting an hour on pieces of neat clay (Stourbridge fireclay) at temperatures of 20 deg., 950 deg. and 1,050 deg. C., showed a percentage loss of weight amounting to 0·13, 0·87 and 0·75 respectively. In a similar test using a mixture of 60 per cent. clay and 40 per cent. fine grog at 20 deg. and 1,050 deg. C., the percentage loss of weight was 0·115 and 0·255 respectively. Other tests were made with mixtures of neat clay with fine or coarse grog—80 clay to 20 grog, and 60 clay to 40 grog—and the proportional amounts of abrasion in the case of two rubbing surfaces having the same texture were 1 for the neat clay, 1·3 for 80 clay and 20 grog (fine or coarse), 2 for 60 clay and 40 fine grog, and 2·6 for 60 clay and 4 coarse grog. For mutual abrasion between a neat clay test-piece and another similar piece or one composed of 80 clay to 20 grog (fine or coarse) the proportional amount is 1, between neat clay and 60 clay with 40 fine grog 40, and between neat clay and 60 clay with 40 coarse grog 3. Except for this last result, the indications are that the amount of abrasion tends to increase as the coarseness of the texture—due either to increased amount or to larger grade of the grog—increases.

Determinations were also made with added loads (of 100 grammes and 500 grammes) on neat clay blocks fired at 1,000 deg. C., the weight of the test-piece and clamp being about 140 grammes. In the case of some test-pieces made of clay and ganister that had been fired at 1,200 deg. C., with no load on the arm, the loss due to abrasion was negligible.

The general conclusions were as follows :—

(1) Fine-grained firebricks resist abrasion more than those of coarser grain, and the admixture of grog, whether in increasing quantity or increasing size of grain, decreases resistance to abrasion.

(2) Abrasion appears to increase at higher temperatures.

(3) Hard firing of the bricks tends to decrease abrasion.

(4) Increase of abrasion is caused by the addition of load to the wearing surfaces.

These are only what would be expected, but it is satisfactory to have them definitely established.

The next paper by Professor J. W. Cobb, B.Sc., F.I.C., and Mr. H. S. Houldsworth, M.Sc., which, owing to shortness of time was taken as read, was entitled "*The Behaviour of Clays, Bauxites, &c., on Heating.*" This relates to work done in continuation of an investigation, some results of which have already been reported in the last volume (22) of the Transactions of the Ceramic Society. The present contribution relates to changes in porosity, density and refractive index.

The porosity did not change between 100 deg. and 400 deg. C., but increased by 1·6 per cent. on heating for 24 hours at 450 deg. C., the temperature at which rapid dehydration of the clay had previously been found to take place. The porosity increased another 1·5 per cent. on firing, to 550 deg. C. It should be remembered that the process of dehydrating kaolin at 450 deg. C. is continued (although very slowly) after a 24-hour period, so that the further increases in porosity were probably due to further slight dehydration of the clay as well as to any further chemical decomposition of the clay molecule or crystal unit which might have occurred. The porosity slowly increased on heating to higher temperatures, being 1·4 per cent. greater at 1,000 deg. C. than at 550 deg. C. Thus the shrinkages of the kaolin test pieces could not be due to decreases in their porosities.

The true specific gravity of the clay (kaolin) remained unaltered up to 400 deg. C., but decreased from 2·642 to 2·521 on firing at 450 deg. C., and then to 2·510 at 500 deg. C. The true density of the kaolin had reached a minimum value when dehydration was complete. Little further change in specific gravity took place up to 600 deg. C., but at 650 deg., 700 deg., 750 deg., and 800 deg. C. small increases in density occurred. These changes are in agreement with the slight shrinkages described at 625 deg., 680 deg. and 760 deg. C. in a previous report. There was only a small further change at 850 deg. C., but on heating to 900 deg. C. the specific gravity increased from 2·568 to 2·608, corresponding with the large shrinkage which took place at 880 deg. C. On heating for 24 hours at 950 deg. C., the specific gravity increased from 2·608 to 2·688, this change being probably associated with the large shrinkage at 950 deg. C. Little further change in density was detected at 1,000 deg. C.

Thus pronounced changes in the clay molecule, as indicated by alterations in the specific gravity, occurred at 400 deg. to 450 deg. C., 850 deg. to 900 deg. C., and 900 deg. to 950 deg. C., corresponding with the dehydration of the clay at 450 deg. C., and the shrinkages at 880 deg. and 950 deg. C. respectively, while smaller changes took place at 600 deg. to 650 deg., 650 deg. to 700 deg. C., 700 deg. to 750 deg. C., 750 deg. to 800 deg. C., and were probably associated with the small shrinkages observed at 625 deg., 680 deg. and 760 deg. respectively. These latter changes may possibly be due to changes in the small quantities of impurities present in the clay rather than to the kaolinite itself.

The refractive index of the kaolinite crystals was not altered by firing at 400 deg. C., but it decreased from 1·564 to 1·543 on heating at 450 deg. C., due no doubt to the dehydration of the crystals. The refractive index decreased from 1·543 to 1·518 after heating to 500 deg. C., and this further decrease was probably due to the completion of that dehydration. The refractive index, as well as the specific gravity, attained a minimum value when dehydration was complete. After this stage the crystals were not so transparent as before dehydration, and the refractive indices were more difficult to determine. Little change in refractive index took place from 500 deg. to 700 deg. C., but at 800 deg. C. the index of refraction increased slightly, the increase being more pronounced at 850 deg. and 900 deg. C., due probably to the same change as that producing the shrinkage about 880 deg. C. Practically no further change occurred at 950 deg. C., but a further increase in the refractive index was detected at 1,000 deg. C., probably due to the change producing the shrinkage at 950 deg. C., which might have occurred at a slightly higher temperature with the pure kaolinite crystals than with the less pure kaolin.

Summarising, it would seem that definite changes in the kaolinite molecule, or crystal unit, as shown by changes in the specific gravity and refractive index, occurred about 450 deg. C., the temperature at which rapid dehydration began, and at 880 deg. and 950 deg. C., where large shrinkages were observed together with a rapid evolution of heat at the latter temperature. The results indicated the possibility of minor changes at 625 deg., 680 deg. and 760 deg. C., at which temperatures kaolin exhibited very slight shrinkages. The porosities of the test-pieces increased gradually as the firing temperature of the kaolin was raised up to 1,000 deg. C. The true density of the kaolin, and presumably the bulk density and the refractive index of the kaolin crystals, had reached their minimum value when dehydration was complete.

Dr. L. M. Parsons next read his paper on "*Dolomite.*" Dolomite is usually a stony substance of pale yellow colour, but it may be of a light grey tint and is then very difficult to distinguish from limestone. Sometimes it is much darker, and closely resembles a dark sandstone. Occasionally it is tinted bright red by iron oxide. Sometimes it is very compact, at other times porous and friable. All these varieties may occur in quite a small area, as in the district a little to the north of the Leicestershire coalfield. Some dolomites are quite barren of fossils, while others contain many organic remains (corals, shells, &c.).

Chemically, dolomite is a double carbonate of calcium and magnesium, and must not be confused with a mere mixture of these carbonates, such mixtures being known as magnesian limestones. Magnesian limestones have a very variable proportion of magnesium carbonate, the formula being written $CaCO_3 + MgCO_3$, and the proportion of magnesium carbonate may be anything from 1 per cent. to over 40 per cent. The formula for dolomite is $CaMg(CO_3)_2$, and the proportion of magnesium is always 45 per cent. for a perfectly pure dolomite, but such pure dolomites are rarely found in quantity. Most of the extensive dolomites contain a small proportion of uncombined calcium carbonate (calcite) intimately mixed with the dolomite.

For commercial purposes the best rocks are those dolomites which fulfil, as far as possible, the following conditions :—

(1) The dolomitisation should be sufficiently extensive to warrant a large supply of material.

(2) The proportion of magnesium carbonate should be high—as near the 45 per cent. of a theoretically pure dolomite as possible.

(3) The chemical composition should be fairly constant over areas sufficiently large.

(4) The rock should be of compact and uniform texture, loose dolomites which weather to "dolomitic sand" being of less value than the tougher compact varieties.

Stated very broadly, there are two distinct groups of dolomitic rocks, primary and secondary. The primary group includes those dolomites which are produced—either chemically or mechanically — in the dolomitic state originally, and are not formed by chemical alteration of rocks first existing as normal limestones. The secondary group includes those dolomites formed by the chemical alteration of rocks originally deposited as ordinary limestone, such alteration being brought about, in most cases, by the action of water containing magnesium salts in solution, and, much more rarely, by heated vapours containing magnesian substances.

Two types of primary dolomites are of some interest :—

(1) Precipitated dolomites or proto-dolomites. These are formed by deposition (precipitation) from old salt-lake waters, along with such other minerals as gypsum, rock salt, &c. Such dolomites would be remarkably uniform in character, and excellent for practical purposes. Unfortunately this type of dolomite does not occur in our country. The Permian magnesian limestone which extends from Durham to South-East Nottinghamshire, is of similar origin, but is not a true dolomite, the percentage of magnesium compounds being very variable, though true dolomite is scattered through it irregularly as occasional nests, patches, veins, &c.

(2) Mechanically, formed dolomitic sediments. These arise from prolonged weathering of old dolomitic rocks, and transport by river action to the sea, with eventual formation of new dolomitic rocks. Such dolomites are rare in this country, and limited in extent. Some fragmental dolomites consist of dolomitic lumps cemented together by non-dolomitic material, while in other cases non-dolomitic fragments are cemented together by dolomitic material.

Secondary dolomites fall into two main types :—

(1) Contemporaneous dolomites. In the formation of these, the accumulation of calcareous material on the bed of the sea, instead of becoming a more or less normal limestone, is subjected to the action of magnesium salts dissolved in the overlying sea water, and so the change takes place before the consolidated material becomes land.

(2) Subsequent dolomites. In these the chemical change was effected by ground waters containing dissolved magnesium salts percolating through limestones which formed part of the land—of course, long after the deposition of the original limestone. Such action has often been only partial, and dolomite has been produced in veins, streaks and patches.

The dolomites of most use commercially are contemporaneous dolomites and such subsequent dolomites as have resulted from extensive, long-continued, and fairly complete alteration of a limestone district.

Contemporaneous dolomites have the following features :—

(1) The dolomite persists along certain beds of rock, and if an unaltered limestone is seen above or below the dolomite, the two kinds of rock are sharply separated by the bedding plane.

(2) The dolomitisation extends for long distances (usually several miles) and the change to ordinary limestone, if seen, is found to be gradual, not abrupt. (Hence patches of dolomite alternating with masses of limestone are not characteristic.)

(3) The chemical composition and texture are fairly uniform over wide areas.

(4) Thin sections under a microscope show either a fine mosaic of irregular-shaped dolomite grains or a mass of small rhombohedral crystals. Where the dolomitisation is more complete the mosaic habit is usual.

(5) The crystals and grains are free from iron oxides arranged centrally within.

(6) They are more compact and durable than subsequent dolomites.

The most extensive examples of contemporaneous dolomites in this country occur in association with carboniferous limestone, as near Cardiff and in the Gower Peninsula in South Wales, at Clifton (Bristol), at Burrington Combe in the Mendips, and in the Shap and Ravenstonedale districts of Westmoreland. One of the most completely dolomitised rocks of this class occurs between Charnwood Forest (Leicestershire) and the small town of Melbourne (in South Derbyshire, about a mile from the Leicestershire border). Several hundred feet of well bedded yellow and grey dolomite are exposed, and worked at Breedon-on-the-Hill and at Breedon Cloud, the composition and texture being very uniform, and the proportion of magnesium carbonate about 40 per cent.

Subsequent dolomites exhibit the following characteristic features—except in very advanced stages of alteration when the whole rock is dolomitised :—

(1) The dolomitisation is not necessarily confined to any particular beds or strata, but passes up or down from one bed to another.

(2) There is a general lack of persistence along any beds, the dolomite being seen sooner or later to pass abruptly into ordinary limestone. (Hence masses of dolomite alternate with masses of limestone.)

(3) A mass of dolomite often sends out veins into the surrounding limestone.

(4) The chemical composition and texture vary even within a small area.

(5) Microscopic sections show either a coarse mosaic of irregular dolomite grains, or (more frequently) large rhombohedral crystals often containing iron oxides or other impurities arranged centrally within the crystals.

(6) There is a marked tendency to form porous structures even on a scale large enough to be seen by the unaided eye.

The best example of a subsequent dolomite in this country is probably the carboniferous limestone area a little west of Wirksworth in Central Derbyshire, the dolomitisation being so nearly complete that some parts contain about 38 per cent. to 40 per cent. of magnesium carbonate. Another interesting example of subsequent dolomitisation occurs in the carboniferous limestone near Abergavenny (Mon.).

The last of the papers read was by Mr. A. F. Greaves-Walker (president of the American Ceramic Society), on "*The Manufacture of Refractories in America.*" Generally speaking, the refractories industry has been slower in adopting mechanical devices to replace hand labour than have other industries, but in this respect the advance has been generally much greater than in Europe.

As regards fireclay products, practically all of the high heat-duty firebricks are made of mixtures of flint fireclay and plastic bond clay in various proportions, the flint clays having a fusion point of cone 32 to 36 and the plastic clays of cone 29 to 32. For medium and low heat duty firebricks plastic fireclays are used almost entirely.

A great majority of all shapes and many 9-in. are hand-made. A moulding gang consisting of one moulder and two off-bearers will usually deliver 3,000 9-in. to the hot floor for a day's work or "task." When delivering to dryer cars set close to the moulding tables, one off-bearer is used, producing the same quantity of bricks for a "day." Hand-moulded 9-in. are always re-pressed,

usually in a hand re-press. Three men usually compose a pressing gang. When running at full capacity, many plants work three shifts of moulders and re-pressers, the gangs relieving one another as soon as they finish their "day" (usually about 6 hours or 7 hours).

Many 9-in. and shapes are now made by the stiff mud or steam press process. Bricks so made are particularly suitable for service where severe abrasion is encountered, as in certain parts of blast-furnace linings. The proper mixture is measured in some plants at the bin chutes by a poidometer or measuring device, which also adds the correct amount of water, and this mixture is delivered to the wet pans or to the pug mill. In other plants the mixture is made at the dry pan, and in this case the bin delivers direct to wet pans or pug mills without measuring. In either case each dry pan is operated by one tender. One man also looks after each wet pan or pug mill, the pan or mill delivering direct to the brick machine. After leaving the automatic cutter (wire) the bricks are passed along on a belt to be re-pressed, and afterwards dried in a tunnel dryer. This is one of the cheapest methods of making firebricks, as the operation is largely mechanical. Two men work the pug mill, brick machine and cutter, and three men do the pressing of each 18,000 to 20,000 9-in. produced.

The soft mud process is generally confined to a dry pan grinding, pugging, forming in the brick machine, and drying without re-pressing. It is a cheap process, and with proper care can give products of high quality. The mixtures of the separately ground materials are made automatically in a poidometer as the ingredients are delivered to the pug mill, and the water content is controlled in like manner.

With the new automatic brick machines, six men can make and handle from 4,000 to 5,000 per hour. The machine sands the moulds, makes the bricks, dumps them and delivers them on pallets beside the dryer cars. The bricks are of good workmanship and it is not necessary to re-press them unless a smoother finish is desired.

The dry press process is a simple process, used formerly only with soft clays, but has recently been used for bricks made from nothing but flint clay. Some clays or mixtures work very much easier than others. The presses can usually produce 1,800 to 2,000 9-in. bricks per hour.

For drying, the hot floor was mostly used, but is being largely replaced by the tunnel dryer heated by waste heat from cooling kilns.

In recent years humidity dryers have been installed in many plants, and have reduced both the drying period and the breakage. The temperature of the humidity dryer is automatically controlled.

For burning firebricks, the round down draught kiln is mostly used, the usual inside diameter being 32 ft., but some recent ones are 36 ft. and 40 ft. The kiln is usually set with firebricks to about 60 per cent. to 80 per cent. of its full holding capacity (100,000) if set up to the crown. A few car tunnel kilns are in use, including a Dressler kiln in which the most difficult glass-house shapes are being burned with perfect success and practically no loss, the heat being taken to cone 12. The average burning temperatures for high grade fire-bricks in different districts range from about cone 7 or 8 to cone 14 or 15.

For burning silica bricks, round down-draught kilns of 32 ft., 36 ft. and 40 ft. diameter are generally used, the product being burned at cone 18 to cone 20, and the burning time lasting from 6 days to 12 days. The setting of silica kilns is carried almost up to the crown. In a commercial burn from 80 per cent. to 82 per cent. of the quartz is inverted. In a machine used for making silica bricks sufficient mud to fill the moulds is dropped from a height that gives it the same force as would be used by a hand moulder in filling. The machine fills the moulds, strikes off the excess, "slicks" the bricks, and dumps them in pallets. It also cleans and sands the moulds. Labour is used only to feed the pallets and take them away and place them on the dryer cars. A very small amount of power is required.

For magnesite and chrome products, no bonding agent other than water is used. Special mechanical presses, giving nearly 10,000 lb. per square inch, make four bricks at a stroke, and a humidity dryer is used for drying.

Portable electrically-driven car unloaders and conveyors—self-contained belt conveyors on wheels—have done much to eliminate labour in unloading raw materials and coal. On most plants coal is distributed to the kilns with close coupled motor trucks with dumping bodies. Loading is done from bins or car unloaders which eliminate the slow shovel loadings.

The Schaffer poidometer, now used to measure and weigh automatically mixtures of clays and water between bins and pug mill, has eliminated the pug mill operator. Where wet pans are used, automatic weighing or measuring hoppers are installed in the discharge chute of the bin, which requires only the pulling of a lever in the hands of the pan operator to deliver a standard charge to the pan.

The use of variable speed motors and chain drive (instead of belts) has added tremendously to plant efficiency as well as conserving floor space.

The newest types of soft mud brick machines sand the moulds, fill the moulds, strike off excess clay, bump the moulds, dump bricks on pallets, put pallets on conveyor, and return empty moulds to machine. Six men will produce from 4,000 to 5,000 9-in. bricks per hour on these machines, handling pug mill, machine, pallets, and dryer cars.

DIESEL ENGINE USERS ASSOCIATION.—At the next meeting of the Diesel Engine Users Association which is to be held on Friday, June 8, at the Institution of Electrical Engineers, a paper on the subject of "Losses in Heat Engines and Means of Avoiding Them" will be read by Engineer-Commander W. P. Sillince, R.N.

BOILER EXPLOSION ON BOARD A DUMB BARGE.

A PRELIMINARY inquiry has been made by the Board of Trade, under the provisions of the Boiler Explosions Acts, 1882 and 1890, with regard to the cause and circumstances attending the explosion of a boiler on board the Cretarch, on October 1, 1922, whilst the vessel was off Dungeness on a voyage from Shoreham to the Tyne. The vessel was owned by the Crete Shipping Company, Limited, managers Messrs. Stelph and Leighton, Limited, 180, Piccadilly, London. Fortunately no one was injured by the explosion.

The boiler was of the "Spencer Hopwood" vertical type. The mean diameter of the shell was 4 ft. 6¼ in., and the height of the boiler was 10 ft. 3 in. There was a vertical fire-box, passing through the upper part of which were 62 water tubes; 54 of these tubes were 2¼ in. in diameter and 10 S.W.G. in thickness, and 8 were 2½ in. in diameter and ¼ in. in thickness. The rake of the tubes from the horizontal was 1½ in. per foot. The boiler was fitted with the usual mountings, including a pair of direct spring-loaded safety valves, adjusted to lift at a pressure of 150 lb. per square inch, for which pressure the boiler was designed. The boiler was made by Messrs. W. H. Spencer and Co., Hitchin, Hertfordshire, in 1918, and was therefore, about four years old at the time of the explosion. As far as could be ascertained, no repairs had been necessary since the boiler was built.

The vessel was insured against total loss only, for the voyage from Shoreham to the Tyne, with the Eagle, Star and British Dominions Insurance Company, Limited, Lloyd's Underwriters. The boiler was last inspected in August, 1922, by Mr. William Stoner, of Shoreham.

The nature of the explosion was such that a tube situated in the lowest row and second from the back opened out for a distance of 1½ in. in a longitudinal direction and ¾ in. in width. Through this opening the water from the boiler escaped into the stokehold. The opening was on the lower surface of the tube, nearest the fire.

The explosion was caused by overheating of the tube under working conditions, due to a deposit of salt.

Mr. T. D. Ferrier, Engineer-Surveyor to the Board of Trade, in his report, states the Cretarch was a concrete sea-going dumb barge of 688 gross tons, built at Poole in 1919. The boiler which exploded was used for supplying steam to the steering engine, capstans, towing windlass, and pumps on the vessel. About the beginning of April last, Captain William Edwin Staveley, marine superintendent, proceeded to Shoreham for the purpose of making the Cretarch and a number of similar vessels ready for sea. He employed Mr. William Stoner, an engine fitter, of Shoreham, to examine and clean the boilers of these vessels, and to prepare the boilers and machinery for sea. Stoner opened up the boiler on the Cretarch in August, examined and cleaned it, and, in his opinion, everything was satisfactory. The boiler was then closed up and filled with fresh water. Fresh water was used until about the end of August, when the vessel was moved to another berth where fresh water could not be obtained. From this time until the vessel sailed it had to be moved on several occasions for the purpose of allowing other vessels to berth. Steam had to be used for this purpose, and sea water was used in the boiler. Stoner stated that this was done on Captain Staveley's instructions. During the five weeks' working of the boiler after cleaning it was blown down twice. Stoner had tested the density of the boiler water on one occasion only, and so far as he could remember, the density was not very high. He appeared to have understood the use of the salinometer, having had experience of using sea water in boilers when engineer at sea, but had no experience of using sea water with this particular type of boiler. The salinometer had to be obtained from another vessel, and it was returned before the Cretarch sailed.

On the morning of September 30, Stoner raised steam on the boiler, and about 6.30 p.m. the crew came on board and the fireman of the crew relieved him of his duties. He told the fireman, James McRitchie, that he was using sea-water feed for the boiler, and that there was a little salt showing, but the fireman made no complaint. McRitchie was shown a piece of wire for clearing the water gauge, which had been giving trouble. McRitchie saw salt on the boiler mountings and on the sludge-hole doors, and informed Captain Staveley and also the master of the vessel, Angus McPhee, that it would be advisable to stay in port for a tide, to see if the boiler was all right. Captain Staveley said the vessel had to sail at once as the tug was waiting. Captain Staveley and McPhee both stated that no complaint was made to them regarding the condition of the boiler before the vessel sailed. The vessel left the harbour at Shoreham at about 8 p.m. on September 30, and at about 9.30 p.m. it finally got under way for the voyage. During this time, McRitchie came to the conclusion that the water in the boiler was very dense, and he looked for a salinometer, but could not find one on board. The water gauge was becoming choked, and he had to clear it with the wire beforementioned. At 8.30 p.m. he blew the boiler down from full glass to about 2 in. of water in the glass, a distance of about 9 in. From that time to about 7.30 a.m. of October 1, the boiler was blown down seven or eight times, and shortly after 7.30 a.m. the explosion occurred when a pressure of 100 lb. was showing on the steam gauge.

Continuing his report, Mr. Ferrier states that he examined the boiler after the explosion and found that 17 of the lower water tubes were solid with salt, and all the other tubes contained a heavy salt deposit, which was thicker in the lower tubes than the upper. The restricted water space at the bottom of the boiler was full of soft salt sludge. At the fire-bar line the salt was caked hard, and in some parts completely filled the water space. Just above the fire-bar line the salt deposit on the fire-box was ⅛ in. in thickness, the incrustation gradually decreasing in thickness up the fire-box, there being little or none on the fire-box top. One water-tube had failed, and the fire-box plate at the left-hand side of the fire-door was distorted over a roughly circular area about 13 in. in diameter; the depth of the bulge was about 3 in. It was probably due to the comparatively new condition of the boiler that the damage was not more extensive. The vessel had provision for carrying fresh water, and this should have been supplied for the voyage, which, under favourable conditions would probably take at least two days, the boiler being under continual steaming during this time. In a boiler of this type the tubes are exposed to the direct heat of the fire, and deposit in the tubes is liable to cause overheating. When sea water-feed is used, the density of the boiler water should be regularly tested, otherwise there is positive danger. The boiler water was tested for density on one occasion only, one week before the vessel sailed. It was hardly possible that the large quantity of salt which was in the boiler had all deposited during the period of steaming after leaving Shoreham and it was undoubtedly in a dangerous condition before the vessel sailed. There were signs of salt on the mountings and on the water gauge. Had the density been tested then, and proper action taken, the explosion would have been prevented. The salt deposit on the fire-box sides was in distinct layers, and this points to the fact that the deposits had taken place on more than one occasion.

In reviewing this report, Mr. Thomas Carlton, Engineer Surveyor-in-Chief to the Board of Trade, in his "Observations" states: "This boiler seems to have been worked in a very haphazard manner, nobody connected with its management appearing to understand the ordinary precautions necessary for ensuring safety. Salt water only was used as feed, yet no means were provided by which the attendants could ascertain the increasing density. Finally, the amount of salt in the boiler was such that precipitation occurred and some of the tubes became solid with salt; overheating followed, and failure occurred."

THE OPTICAL SOCIETY.

AT a meeting of the Optical Society held at the Imperial College on Thursday, May 10, 1923, Mr. T. Smith, M.A., vice-president, in the chair, a paper on "*Stereoscopy Re-stated*," by Mr. James Weir French, D.Sc., was read and discussed.

The following is an abstract of the paper: While the phenomenon of stereoscopy has been to a limited extent developed in a practical manner, there appears to have been but little actual research work done within recent years, the impression being a general one that the particular field had been already thoroughly explored. If an attempt be made to reproduce the experiments described by Wheatstone in his original paper, in which his great discovery of stereoscopy was published, it will be found that the results are somewhat different in important respects from those described.

From experiments recently carried out by the lecturer, it appears that stereoscopic vision is possible only within certain limits. For certain pairs of objects, whether on the same or different horizons, there are generally two extreme critical points beyond which stereoscopic vision breaks down. For certain pairs of objects on the same horizon there are two inner critical points. Objects of dissimilar form but approximately the same average angular dimensions can frequently be combined stereoscopically: thus a circle can be combined with a triangle if their average angular dimensions are about equal. When the angular dimensions are very different, combination is generally impossible; thus, for example, a thin line cannot be combined with a thick line or triangle or other form of considerably larger size. When the pairs of objects are dissimilar in size there is only one pair of outer and inner critical points if the objects are on the same horizon and one outer critical point if they are on different horizons. For pairs of objects any of which can be combined together, there are two pairs of such critical points.

Data regarding the positions of the critical points under various conditions are contained in the paper, which also deals generally with the effects of variation of the conditions of observation and particularly variations of the illumination.

DIRECTORY OF PAPER MAKERS, 1923.—This edition, the forty-seventh annual publication, the net price of which is 5*s.*, by post 5*s.* 9*d.*, is edited and published by *The Paper Makers' Monthly Journal*, Messrs. Marchant, Singer and Co., 47, St. Mary Axe, E.C. 3. It covers the whole of the paper trade, and gives a classification of makers, with the makers' names, trade designations, watermarks and trade names other than watermarks. Apart from the directory portion, which is very complete and easy of reference, special chapters deal with the trade customs with reference to paper, and with paper dimensions.

THE GREENLAND RADIO STATION.—The Danish Government has now decided upon the erection of a wireless station in Greenland. Tenders were received from the Marconi Company (700,000 kronen), Danish Radio (Valdemar Poulsen's system) (660,000 kronen), and the German Telefunken Company (540,000 kronen). The contract is to be given to the Danish concern. There will be a main station at Godthaal and two auxiliary stations. The Greenland plant will not be so powerful as recommended by the Radio Commission; its area is limited to Iceland and the Faröe Islands, where adequate telegraphic connection exists, and is not to be extended to America and Denmark, as was originally intended.

THE INTERDEPENDENCE OF ABSTRACT SCIENCE AND ENGINEERING.*

By Sir RICHARD TETLEY GLAZEBROOK, K.C.B., M.A., D.Sc., F.R.S., Hon. M.Inst.C.E.

(*Concluded from page* 602.)

Up to the present, obedient to the President's behest, I have dealt mainly with the organization and methods of engineering research, but my address would be singularly incomplete if I did not attempt an account of some of its recent results and of its marked progress. And here my real difficulties commence. Statistics and the kindness of many friends have made the earlier portion of my task comparatively light.

But now the difficulty is what to select, where to begin. The problems are so numerous in which there is a close connection between theory and practice; they can be found in every branch of engineering, perhaps with more striking effect in electrical and metallurgical science, in the laws of stress and strain, in structural materials and in the fatigue of parts subject to vibration, rather than in the questions which pertain more closely to the domain of civil engineering. Let me first deal briefly and incompletely it must be, I fear, with that branch of electrical engineering—radio, or wireless telegraphy—which at present exercises such a fascination over the popular mind, which is already, and will be to a greater extent in the future, a link to bind together all nations of the earth. Sir William Anderson refers to Preece's early experiments between Lavenock and Flatholme, a distance of eight miles, as a startling consequence of electro-magnetic theory. Now the earth is girdled with a wireless chain depending from two, or at most three, great stations. I have just received from the International Union for Scientific Radio Telegraphy details of a scheme for the determination of longitude in which the principal co-operating stations will be Bordeaux, Annapolis, and Pearl Harbour.

In the year 1865 Clerk Maxwell read before the Royal Society his paper on "The Equations of the Electro-magnetic Field." It was an attempt which has stood the test of time—the conditions which led Lorentz and, later, Einstein, to introduce certain modifications were not considered by Maxwell—to apply mathematical reasoning to those principles, enunciated by Faraday, on which the construction of generators and motors, transformers and practically all electrical machinery is based.

This reasoning led him to the result that the effect of changes in an electric current in a conducting wire would be propagated through space with a speed depending on the two constants† which define the electric and magnetic conditions of the medium surrounding the wire. The values of these constants for air can be found from electrical considerations, and hence the velocity with which electro-magnetic disturbances are propagated can be calculated.

To quote his words:—"We now proceed to investigate whether these properties of that which constitutes the electro-magnetic field, deduced from electro-magnetic phenomena alone, are sufficient to explain the propagation of light through the same substance," and his conclusion is, "The agreement of the results seem to show that light and magnetism are affections of the same substance and that light is an electro-magnetic disturbance propagated through the field according to electro-magnetic laws."

Maxwell found that when the calculations were made the resulting value for the velocity‡ was approximately equal to the velocity of light. The work was extended in his "Treatise on Electricity and Magnetism," published in 1873. The values of the velocity of light and the velocity of propagation of electro-magnetic waves were not known then with present-day accuracy, and he concludes that they are quantities of the same order of magnitude. A glance at present-day figures shows that they are identical, and the electro-magnetic theory of light is universally accepted. Nor was the result true only for propagation through air or interstellar space; such observations as were then available showed that, in all probability, it held for all transparent media, though there were discrepancies, known now to be due to dispersion, which required explanation. But there was a wide gap between this theoretical deduction of Maxwell and the wireless telegraphy of to-day, which needed many more investigations in "pure" science before the bridge was complete. We at the Cavendish Laboratory—I was a student at the time—implicitly believed in its truth, but no one had received electro-magnetic vibrations, at any rate to his certain knowledge. The method of generating them and the means for measuring them were still to come.

For the former we have to go back to a remarkable paper§ by a very distinguished honorary member of this Institution, Lord Kelvin. Helmholtz‖ seems to have been the first to conceive that the discharge of a condenser through a wire might consist of a forward and backward motion of electricity between the coatings—a series of currents in opposite directions. Sir William Thomson took up the question mathematically and investigated the phenomena. He showed that under certain conditions there would be oscillations of periodic time $2\pi\sqrt{LC}$, where L is the inductance of the coil and C the capacity of the condenser. These oscillations must, according to the theory, give rise to waves travelling out into space with the electro-magnetic velocity. Fitzgerald, at a meeting of the British Association, had predicted in 1883 that they might be produced by utilising the oscillatory discharge of a Leyden jar, and Sir Oliver Lodge in 1887 produced and detected them. For their detection the principle of resonance was employed. Any mechanical system free to vibrate has its own period of oscillation, and the application to it of a series of small impulses at intervals consonant with the free period of the system results in a disturbance of large amplitude; so, too, an electric system having capacity and inductance has its own period of electrical oscillation, and, if this coincides with the period of incoming electrical waves, electrical disturbances of a magnitude which can be detected by our apparatus are set up. It is necessary that the receiver and the transmitter should be in tune. Lodge made use of this principle, and, by receiving the waves on wires adjusted to resonance with his Leyden jar and coil, was able to detect them. David Hughes, working in the early eighties, had already detected such oscillations, but was discouraged from pursuing the subject.

In 1879, in consequence of the offer of a prize by the Berlin Academy, the attention of Heinrich Herz, then a student under Helmholtz, was drawn to the problem of electric oscillations and their detection. He came to the conclusion that with the means of observation then at his disposal, "any decided effect could scarcely be hoped for, but only an action lying just within the limits of observation." The investigation was laid aside, only to be revived in 1886 by a chance observation of the effect of resonance in two circuits which happened to be in tune, and his realisation of the fact that herein lay the means of solution of his problem. The great man and the not-too-small theory of the first James Forrest Lecture had met. His paper "On Very Rapid Electric Oscillations" appeared in Wiedemann's "Annalen," vol. xxxi for 1887, and from the experiment came verification of Maxwell's theory, the basis of all our knowledge of wireless.

Fitzgerald called the attention of English physicists to the work at the British Association Meeting in 1888, and Lodge exhibited many of the effects of the waves at the Royal Institution in 1889. The investigations which led to such brilliant results were inspired by the desire for knowledge; the idea of their practical application was entirely absent; signalling by wireless waves was not foreshadowed until Crookes suggested it in 1892, and, in 1893, the year of Sir William Anderson's Lecture, Lodge heard of Branly's coherer and applied it to the rectification and reception of wireless waves. From this, started the investigations of many of those whose names as pioneers are familiar to all. But another discovery in pure science was necessary to complete the work.

Edison had shown in 1883 that if an insulated electrode was inserted in an ordinary glow lamp there was a current of negative electricity from the filament to the electrode—the emission of negative electricity from a hot body had been observed by various experimenters—and Fleming made some observations about this date on the Edison effect. In 1904 he applied them to produce a valve rectifier for high-frequency oscillations by connecting one pole of his receiving circuit to an insulated plate or cylinder within a carbon lamp, of which the negative electrode forms the other pole of the receiving circuit. When the filament is made incandescent, negative electricity can readily pass from it to the insulated plate and hence into the receiving circuit; the flow of positive electricity in the same direction is checked; the lamp has a rectifying action.

Dr. Lee de Forest improved this oscillation valve a little later, making it an amplifier as well as a rectifier by placing between the filament and the plate or cylinder a grid of metal wire connected to an external source of electromotive force, by means of which its potential can be varied. There is ordinarily a current of negative electricity passing from the filament to the plate—the plate current it is called—through the interstices of the grid. By varying the potential of the grid this current can be varied, and the conditions can be so adjusted that small changes in the potential of the grid will produce large changes in the plate current; the plate current is passed through the primary of a step-up transformer, in the secondary of which is the receiving telephone, and the effect is thereby made audible. The grid is connected to one pole of the circuit receiving the incoming waves, and the small variations of potential which they produce thus give rise to large variations of the plate current, and hence the sound is amplified. By placing a number of valves in series very large amplifications are possible.

The other uses of the valve are very numerous. It is now employed as a transmitter for wireless work, while it finds many applications as a source, or, rather, regulator, of vibrations of comparatively short period. The Post Office has used it as an amplifier of speech, while Mr. F. E. Smith has applied it as a source of sound in connection with the measurement of audibility. The whole of those arose from Edison's observation of the discharge of negative electricity from the heated filament.

To quote again from the first Forrest Lecture:—"The engineer must banish from his mind the idea that anything can be too small or too trifling to deserve his attention." For the modern development of the valve, through the researches of those who have brought it to its present excellence, has rested on a still smaller entity; the electron, a body with a mass of $0{\cdot}900 \times 10^{-27}$ grams, about 1/1800 of the atom of hydrogen, carrying a negative charge of $1{,}591 \times 10^{-20}$ electro-magnetic units* of electricity, first glimpsed by Crookes, then proved to exist by J. J. Thomson.

The appearance of a Crookes tube or vacuum tube when carrying an electric discharge is well known. When the pressure is sufficiently reduced, the tube is non-luminous except for a beam of light which proceeds normally from the cathode—the negative electrode—and penetrates into the tube a distance depending on the pressure; this beam constitutes the cathode rays; if the rays strike the glass at the end of the tube, a vivid fluorescence is produced.

Crookes showed that the beam constituted a current of negative electricity; it could be deflected by a magnet. Experiments by Perrin and J. J. Thomson proved conclusively the existence of the negative charge. Thomson showed also that the stream consisted of an assemblage of minute particles—electrons. He measured the velocity of the particles and the ratio e/m of the charge on each to its mass. Further experiments, of which perhaps those of Millikan are the most important have led to a determination of the charge on the electron, and from this and a knowledge of the ratio the values of e and m, given above, are found. And these values are the same whatever be the nature of the cathode from which the rays take their origin—the mass and charge of an electron are the same whatever be its source. Thus now it is hardly too much to say that nearly all electrical phenomena are conditioned by the presence and motion of electrons. The current in a cable is a stream of electrons; a conductor is a body through which they move freely; an insulator checks their activity. The power that drives our motors comes from them; the light of the electric lamp, the heat that comes from an electric radiator, have their origin in these tiny particles; the plate current of the valve rectifier referred to above is a stream of electrons; when the grid is negatively electrified it adds negative electrons to the stream; when it is positive some of the electrons from the filament are stopped in their passage through its interstices to neutralise the positive electricity it possesses.

Electrical engineering in its many branches is closely bound up with the properties of an electron discovered by men whose sole object it was to advance natural knowledge. Nor is this all: for from the electron came X-rays, though this, perhaps, is hardly the correct way of putting it, as J. J. Thomson's discovery really followed that of Röntgen. About 1894 physicists in many countries were experimenting with Crookes cathode rays. A chance observation made by a skilled worker revealed the fact that the cathode rays produced an effect outside the tube in which they were generated. Röntgen, in the autum of 1895, was conducting an investigation with a vacuum tube wrapped in light-proof paper and noted that a fluorescent screen of Barium platinocyanide lying near shone out when the tube was excited; if he placed opaque objects between the screen and the tube, shadows were cast on the screen, showing that rays, the X-rays, proceeded from the tube in straight lines; while it was quickly found that the rays penetrated substances opaque to light, the penetration depending on the density of the substance. There is no need to dwell on the results that have followed from this and their significance to engineers. X-rays can penetrate 4 mm. to 5 mm. of lead, 12 mm. of tin, 75 mm. of carbon steel, 100 mm. to 150 mm. of aluminium, and 300 mm. to 400 mm. of wood. By their aid hidden cracks or faulty welds can be shown upon metal structures, while they have been employed for many purposes, besides their use in surgery and medicine.

For some time their nature was a mystery. Their rectilinear propagation and the absence of refraction when they fell obliquely on the surface of a medium other than air were difficult of explanation. Now it is known that they are produced by a very rapid change of motion of electrons. When the velocity of an electron is altered, an electro-magnetic wave is produced, and starting from the electron, travels outward with the velocity of light. The frequency in this wave—in the number of vibrations per second produced—depends on suddenness of the change of velocity of the electron. If this is very great the frequency in the resulting wave is also very great. When a beam of cathode rays falls on the glass walls or on the anti-cathode of an X-ray bulb, the electrons are stopped almost instantaneously. Electro-magnetic rays of very high frequency—X-rays—are produced. Their wave-lengths are now known to lie† between 12×10^{-8} cm. and $0{\cdot}17 \times 10^{-8}$ cm. The wave-length of visible light is between $7{,}700 \times 10^{-8}$ cm. and $3{,}600 \times 10^{-8}$ cm.; that of ultra-violet light lies between $3{,}600 \times 10^{-8}$ cm. and 200×10^{-8} cm., and it is to this minuteness of wave-length that the absence of refraction is due. In the hands of Sir William and Professor W. L. Bragg it has been the means of revealing the inner structure of materials in a manner of the utmost importance to engineers. We will return to this later.

Turning now to a less abstract branch of electrical science, a research of great importance to all users of electricity has just been carried through by Mr. S. W. Melsom and his assistants at the National Physical Laboratory with the co-operation of Mr. E. Fawsett at Newcastle. Its object was to determine the permissible current-loading of British Standard cables laid in various ways in the ground, and it was undertaken as part of the work of the British Electrical and Allied Manufacturers' Association already referred to.

The problem is to determine the maximum current which the cable can carry without raising the temperature above some specified figure taken as 65 deg. C. for

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* The twenty-ninth James Forrest Lecture, delivered at the Institution of Civil Engineers, on Friday, May 4, 1923.

† The velocity is given by $1/\sqrt{ku}$, where k is the inductive capacity and μ the magnetic permeability of the surrounding medium.

‡ Messrs. Rosa and Dorsey, of the Bureau of Standards, discussing the various determinations of the electro-magnetic velocity, express the view that the figure $2{\cdot}9980 \times 10^{10}$ cm./sec. is accurate to 1 part in 10,000, while the best results for the velocity of light is, to the same accuracy of measurement, $2{\cdot}9986 \times 10^{10}$ cm./sec. "v." See Dictionary of Applied Physics, vol. ii.

§ *Phil. Mag.*, 1855.

‖ *Uber die Erhaltung der Kraft*, 1847.

* One electro-magnetic unit is the charge transferred by 1 ampere circulating for 10 seconds.

† See "Dictionary of Applied Physics," vol. iv. Radiology.

armoured cables laid direct in the ground, and 50 deg. C. for plain lead-sheathed cables drawn into ducts. In forming the tables with which the research concludes it is assumed that the average temperature of the ground is 15 deg. C.

The heat generated in the cable depends on the current and resistance, while the temperature-rise depends on the heat generated, the dimensions and specific heat of the copper core, the thermal resistance of the insulating material between the core and the outer covering, and the thermal resistance of the ground surrounding the cable. The measurement of these quantities is in no case easy, the calculation of the thermal resistance of the insulator when once its resistivity has been determined is simple for a single-core cable, but complex in the case of three cores; the resistivity of the ground depends on the material of the soil, the amount of moisture present, and the depth of laying; but in the end tables have been drawn up which in the opinion of Mr. Llewellyn Atkinson, the late president of the Institution of Electrical Engineers, will save users tens of thousands of pounds annually, besides reducing the initial cost of the equipment. Figs. 1 and 2* show some of the results attained for continuous and intermittent loading respectively.

Few matters are of more importance to the engineer than the properties, metallurgical and others, of the materials he uses in his structures, and for the knowledge of these he owes everything ultimately to the researches of the seeker after new knowledge. From the time when Sorby applied the microscope to the study of metals and alloys, and Roberts-Austen, and Osmond investigated their heating and cooling curves to the present day there has been continuous progress. Much of this is due to the investigations of the Alloys Research Committee of the Institution of Mechanical Engineers, and a comparison of the earlier reports of that committee with the eleventh report just issued from the National Physical Laboratory shows in an interesting manner the extent to which modern industrial processes rest on pure science and how great is the debt incurred since those early days.

For some time the committee has worked on light alloys, impelled to it in part by the need to develop these for use in aircraft. It is good to learn that, thanks in great measure to the generosity and zeal of Sir John Dewrance, the committee has been reconstituted so as to be more widely representative, and intends in the future to direct its work to the study of ferrous alloys. It is hoped to prepare alloys of iron with other metals, such as chromium and cobalt, which shall be free from carbon, and then to go on to more complex materials. As the memorandum, in which Dr. Rosenhain brought before the committee the proposals for this work, states: "It may confidently be expected that work of this kind, which has never been attempted in this systematic manner before, is likely to lead to results of a far-reaching importance and to the evolution of materials likely to be of very special value to the mechanical engineer." To me it is a matter of very real pleasure that the greater part of the work will go on at the National Physical Laboratory.

The records of the engineering department of the Laboratory are full of investigations which illustrate the inter-dependence of abstract science and engineering. Dr. Stanton has been kind enough to help me to obtain details of some few. The resistance of a body moving through a fluid in which it is completely immersed is either proportional to the relative speed of the two or to a power of the speed very approximately equal to 2; and the line dividing the two is clearly marked. When the motion is streamline in its nature we have to deal with the direct power of the speed; when, however, it is turbulent or eddying, the square of the relative speed comes in. Osborne Reynolds showed, as is well known, by experiments on the flow of liquids down a long pipe that the change from previous steady motion to turbulent occurred when the quantity $v\,d/\nu$ exceeded a certain value which is about 300; in this expression v is the relative speed, d the diameter of the pipe, and ν the kinematic coefficient of viscosity. Turbulent motion it is found resolves itself into steady when $v\,d/\nu$ exceeds 2,000, and this value gives Reynolds critical velocity. Any physical quantity can be expressed in terms of the fundamental units of mass, length, and time. Each of these units may occur in its expression raised to some definite power. If this is done, all the terms in any equation having a physical significance must necessarily have identical dimensions in each of these units respectively. If one term be of the form $a\,M^l\,L^m\,T^n$, where a is a numerical constant, M, L and T represent the units of mass, length and time, and l, m, n are constants, then any other term in the expression must be of the form b, M^l, L^m, T^n, where b is some other numerical constant.

Lord Rayleigh, by an application of this principle, showed that the resistance to the motion of a body through a fluid, assuming no forces to act on the fluid, must be of the form $k\,V^2\,L^2 f\left(\frac{V\,L}{\nu}\right)$, where k is a numerical constant, V the relative velocity, L a length depending on the size of the body, and ν the kinematic viscosity, which is equal to μ/ρ, where μ is the viscosity as ordinarily defined, and ρ the density of the fluid. This result of abstract theory is the basis of all model work in aeronautics, and in this connection will be referred to later. It was applied by Stanton to harmonise the results reached by himself and many investigators who had measured the resistance to flow of fluids in pipes. The friction per unit area, denoted by R, will be of the form $k\,\rho\,V^2 f\left(\frac{V\,D}{\nu}\right)$, and in the curve shown in Fig. 3 the quantity $R/\rho\,V^2$ is plotted against log $V\,D/\nu$ for values of air and water above the critical speed of Reynolds' formula, extending from $V\,D/\nu = 2{,}500$ to $V\,D/\nu = 470{,}000$. The curve is a complete verification of Lord Rayleigh's formula; the resistance is clearly a function of $V\,D/\nu$; below the critical value, the left-hand branch is in good accordance with the hydro-dynamical equation $R = \frac{8\,\mu\,V}{D}$; the right-hand branch shows a value for $R/\rho\,V^2$ gradually decreasing as V D increases and tending to become a straight line parallel to the axis of abscissæ; the resistance tends to become proportional to the square of the speed.

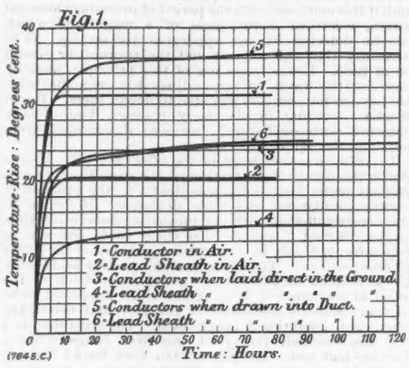
Again, it follows from a further application of Reynolds' theory that the rate of transmission of heat from a heated pipe to a fluid flowing through it, or *vice versa*, depends on the roughness of the pipe. Fig. 4 illustrates this, and shows that the two curves, the one giving the ratio of heat transmitted, the other the ratio of the frictions in two pipes of the same size and material, of which the surface of one had been artificially roughened, and the other quantities involved. Harrison has since extended the mathematics to the case of a complete bearing. The problem requires a knowledge of the difference of radii of journal and bearing, and of the temperature and viscosity of the oil film. Mr. Hyde's recent experiments at the National Physical Laboratory give the relation between the viscosity and the pressure.

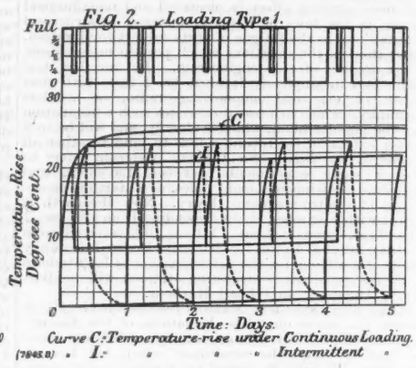
Dr. Stanton has recently succeeded in measuring the pressure in the film over an arc of contact of from 14 deg. to 15 deg. for various oils under a total load of 690 lb. at a journal speed of 1,000 r.p.m. The maximum pressure for castor oil was 3·5 tons per square inch, and the resultant of the vertical components of the pressure approximately balanced the load. At their nearest point of approach the surfaces were only 0·000046 in. apart, while the coefficient of viscosity agreed with that found by Mr. Hyde. Thus the experiments showed that the laws of hydrodynamics hold, and are competent to account for the observed facts, even in a film which is $\frac{5}{100{,}000}$ in. in thickness, and which is subject to a pressure of 3·5 tons per square inch. Fig. 7, taken by permission from Dr. Stanton's paper*, gives the curve of pressure for castor oil.

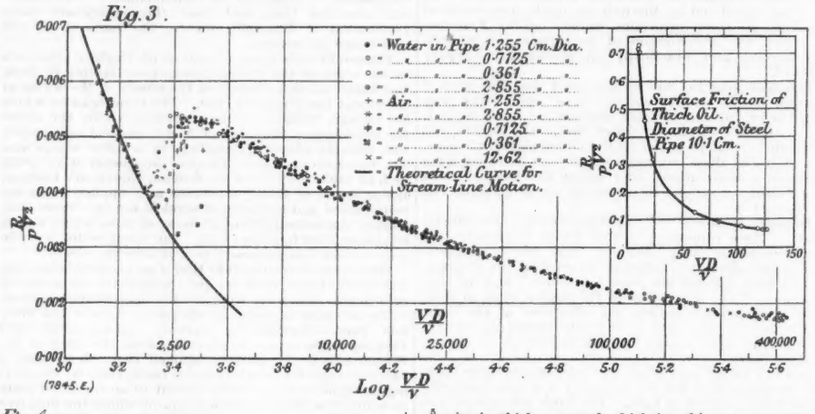
Of great interest to any engineer is a knowledge of the elastic properties of the material with which he deals, and of the changes which go on in the material when the limits of its elasticity are exceeded. For the study of these properties various forms of extensometer have been devised. Professor Dalby's work in this field is well known, and he has himself described his load-extension elastic instrument, which, by a skilful combination of the principle of the weighbar and magnification by the aid of photography, gives a complete record of the elastic properties of the specimen under test in the course of a few minutes in a form which can be readily reproduced and kept for study at leisure.

One such diagram† is shown in Fig. 8. Starting from O with a tension, the spot moves to A along the straight line O A; on reversing and putting on a compressive load it moves to B, and so long as the elastic range is not exceeded, it traverses the line A B accurately. But if the tension stress is increased beyond A the spot moves up to C and then rapidly falls to D, the specimen is broken down. On reducing the load at D to nothing, the spot moves to E, D E being parallel to the elastic line A B, and on putting on a compression the spot moves to F. On removing the compression, there is motion to G parallel again to the elastic line, and on applying tension we have motion from G to H. By repeating the operations we get a second similar loop H I J, but of larger area. The breaking down of the material is accompanied by the formation of slip bands described long since by Ewing and Rosenhain, and Professor Dalby has described in a diagrammatic way changes due possibly to the sliding of the material along the slip bands and its elastic recovery which give generally an explanation of the results shown in the figure.

But another paper read recently as the Bakerian







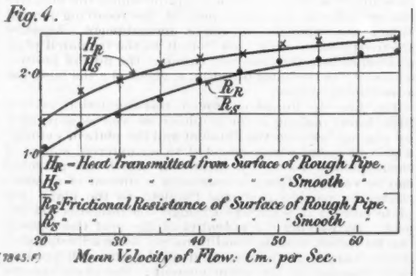


Fig. 4.
H_R/H_S
R_R/R_S
H_R = Heat Transmitted from Surface of Rough Pipe.
H_S = " " " Smooth "
R_R = Frictional Resistance of Surface of Rough Pipe.
R_S = " " " Smooth "
Mean Velocity of Flow: Cm. per Sec.
(7845.F)

* Reproduced by permission from the Second Report to the Institution of Electrical Engineers.

* Proc. Inst. Mech. E., 1922, vol. ii, page 1,138.

† Reproduced by permission from Proc. Royal Soc., Series A, vol. ciii (1923), page 13.

Lecture to the Royal Society by Mr. G. I. Taylor and Miss Elam, enables us to see further into the mechanics of strain. The action of a diffraction-grating is well known: the grating consists of a plate of polished glass or metal on which is ruled a series of fine lines at equal distances apart at a rate of from say, 6,000 to 15,000 to the inch. Thus the distance apart of the lines of a grating may be of the order $15{,}000 \times 10^{-8}$ cm., or, say, from two to four times the wave length of visible light.

When a beam of homogeneous light falls normally on such a grating from a small source, preferably a narrow slit parallel to the lines of the grating, a series of bright images of the source is formed. If A be the angle which the line forming one of these images to the centre of the grating makes with the normal, λ the wave-length of light and ϵ the distance between the grating lines, then theory and experiment both show that the relation $\sin A = m\lambda/\epsilon$ holds where m has the values 1, 2, 3, &c. These images are said to be diffracted images of the source, and it is clear that if they are to be formed, λ and ϵ must be quantities of the same order, while the equation can be used to determine λ if ϵ is known, or *vice versa*. Similarly any natural material reflecting light from a surface regularly marked with a fine structure resembling the lines of a grating, or arranged as a series of thin films of varying reflective power, can produce diffraction effects, and the colours of various material objects are due to these.

X-rays, however, are not diffracted by any artificial grating, however fine, and we see the reason. The wave-lengths of the rays lie between 12×10^{-8} cm. and $0{\cdot}17 \times 10^{-8}$, being only from one to ten thousandths of the distance between the lines of the grating; thus the diffraction angles are far too small to be observed.

But a crystal owes its regular form to the regular spacing of the atoms of which it is composed, and the distance between the various planes of symmetry in which these atoms lie is of the same order as the wave-lengths of the X-rays. It occurred to Laue in 1912 that this regular spacing might provide a natural medium suitable for the diffraction of X-rays, and he predicted the directions in which diffraction would take place, making certain assumptions as to the nature of the spacing of the crystal atoms. This was verified in 1913 by Frederick and Knipping.

The theory was carried a stage further by W. L. Bragg in a paper in the Cambridge Philosophical Proceedings for 1912, and in the hands of his father, Sir W. H. Bragg, and himself has developed into a method by which the molecular configuration of the crystal can be determined, and changes produced by alterations in its form be measured.

It is not possible, however, to apply this to a piece of steel under stress. The steel consists of a multitude of microscopic crystals embedded in a non-crystalline cement; their axes and planes of symmetry are oriented in all directions, and regular diffraction in any one direction can never be observed. Much work, however, has been recently done on aluminium and its alloys, and Dr. Carpenter and Miss Elam, working at the Imperial College, discovered a method of producing large specimens of aluminium containing only a small number of crystals; in their final experiments a number of bars of diameters 0·564 in. and 0·798 in. were so treated that each consisted of one single crystal. Tensile tests on bars consisting of but a few crystals showed remarkable results. The problem of determining the state of strain in such a crystal when under stress was then attacked by Mr. G. I. Taylor, and in the Bakerian Lecture he and Miss Elam describe the results of gradually straining a test-piece of rectangular section and dimensions $1{\cdot}0 \times 1{\cdot}0 \times 20{\cdot}0$ cm. The faces were marked with lines parallel to their length and cross lines oblique to these, and gradually strained in eight stages up to an extension of 72 per cent. At each stage the angle between the faces, the distances between the cross lines, and the angles those lines make with the longitudinal axis were measured, while the positions of the crystal axes were also determined by aid of X-rays. Thus the distortion of the crystal was determined and also the position of the crystallographic axes relative to the direction of the stress. The conclusion was reached that up to an extension of 40 per cent. the distortion took place entirely by slipping along a plane equally inclined to the three principal axes of the crystal, a plane denoted by the symbol (III) as employed by crystallographers.

Now there are four such planes parallel to the faces of a regular octahedron, and on each of these there are three crystallographically similar possible directions of shear. It was found that the slipping took place along that possible direction of shear in which the shearing force tending to produce motion is of maximum value. In the end the result of the successive slips was that the crystal axes so placed themselves that two of these octahedral planes then made equal angles with the axis of the specimen. The figures show that this had probably happened before the last strain which brought the total extension up to 72 per cent., and that then slipping occurred along both these planes with the result that the specimen breaks with a chisel edge instead of the usual conical fracture of an ordinary test-piece. Thus we may perhaps conclude that in each of the crystals composing a steel test-piece there are certain planes and directions along which slipping can take place. As the test-piece is strained, each crystal slips along that plane and in that direction in which the component of the force producing the strain is greatest. The final strain is the resultant of all these microscopic slips. So long as the strain is not too great the crystal is elastic and recovers its original form when the stress is removed. X-ray have in this way revealed to us much that was hidden in the mechanism of stress and strain.

Thirty years ago Sir William Anderson referred to the phenomenon of fatigue in engineering materials, as shown in the breaking of locomotive axles, screw propeller-shafts, and other parts subject to alternating or rapidly-varying conditions of stress. Since that time much abstract science has been applied in the attempt to elucidate the problem, and many methods of determining the fatigue limits have been devised. It must suffice here to refer to the ingenious model* by the aid of which Professor Jenkin of Oxford has been able to illustrate the mechanism of failure, and to give a reasonable explanation of many of the principal phenomena observed, and to mention the modification of the well-known Wöhler method of determining the fatigue limits devised by Mr. Gough of the National Physical Laboratory and illustrated in Fig. 9. A stainless steel mirror is attached to the specimen in such a manner that it is at right angles to the axis. A small source of light which can move along a vertical scale is adjusted so that its image is visible in a telescope having its axis horizontal and directed to the mirror. When the specimen is unloaded, the light remains visible as it rotates. If a load be gradually applied, the specimen bends, and the light is shifted so as always to remain on the cross wire of the telescope. Its position can be read to 0·01 in. If the scale-reading is plotted against the load, a straight line is at first obtained followed by a deviation turn when the limiting range of stress is reached. The time taken for an observation varies from 10 minutes to half an hour, depending on the rate of loading; but in any case the reduction of time from that needed for the old method is very great. Fig. 10 shows some of the curves obtained.

No branch of engineering owes more to abstract science than aeronautics. Lord Rayleigh's work on dynamical similarity is at the base of all wind-channel work on models. In a wind-channel the forces on a model aircraft due to its motion relative to the air, or the thrust and torque of a model propeller, are measured, and from these, using the principle of dynamical similarity, the corresponding full-scale effects are inferred from the assumption that they are proportional to the square of the linear dimensions and the square of the speed. Strictly this implies, as we have seen, that the quantity $f\left(\frac{VL}{\nu}\right)$ has the same value for model and full scale. Thus either this quantity is constant or $\frac{VL}{\nu} = \frac{V_1 L_1}{\nu_1}$, where the subscript refers to the full scale. Since air is in both cases the surrounding medium $\nu = \nu_1$ and we must have $VL = V_1 L_1$. This, however, is impossible if L is necessarily much less than L_1, and it is impossible to make the speed in the wind-channel proportionately greater than that of the full-scale machine. We are driven, then, to the first alternative, that for a strict comparison $\left(\frac{VL}{\nu}\right)$ must be a constant.

Experiments such as Dr. Stanton's on flow of air and water in pipes, and the actual measurement of the forces on models at different wind speeds, show that this is very approximately true in most cases. Airship models of good performance form an exception to this statement; but the corrections required to model results are now generally accepted, and there is a gratifying agreement both between different wind-channels and the conclusions from model and full-scale experiments. However, this may be, the problem of the flow of air round an aeroplane is no easy one, and there is ample opportunity for abstract science to influence still more engineering practice.

The development of the internal-combustion engine is another engineering problem which owes much to exact science. Its foundation is contained in the celebrated memoir of Sadi Carnot: "Réflexions sur la puissance motrice du feu et sur les machines propres a développer cette puissance," published almost exactly 100 years ago—Paris, 1824—in which he sets out "to establish reasoning applicable not only to steam engines, but to every imaginable heat engine, whatever be the working substance and whatever be the manner in which it is employed"; and is led to the remark, "wherever there exists a difference of temperature there can be a production of motive power."

It is a long journey from this, either through the steam

* Royal Soc. Proceedings, vol. ciii, 1923, page 121.

Fig. 5.

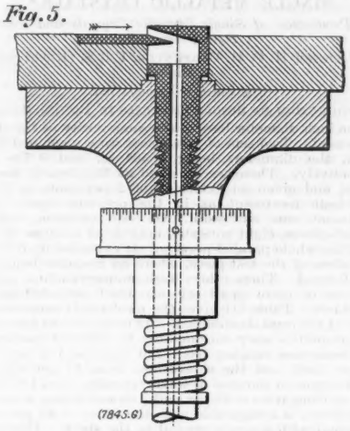


Fig. 7.

Dia. of Bearing	= 1·06″
Length of Journal	= 2·50″
Dia. of Journal	= 1·00″
Temp. of Film	= 49·0° C.
Speed	= 1000 R.P.M.
Total Load	= 690 Lb.
Arc of Contact of Oil Film	= 15 Degrees.

Least distance between surfaces of Journal and Bearing = 0·000046 at 3·0 degrees to left of Vertical through centre of Journal.
Observed Pressure-Distribution
Pressure Calculated

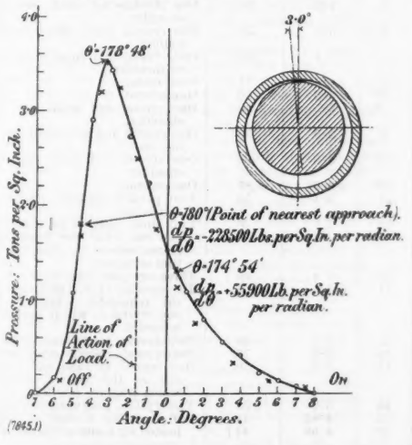


Fig. 6.

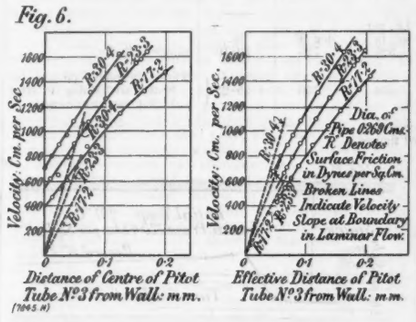


Fig. 8.

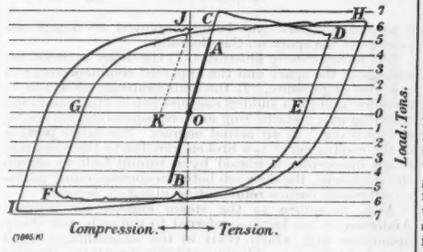
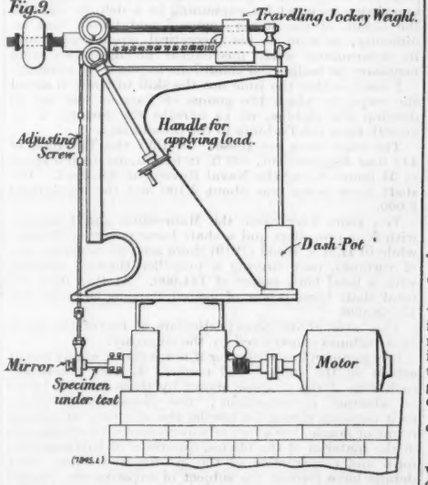


Fig. 9.

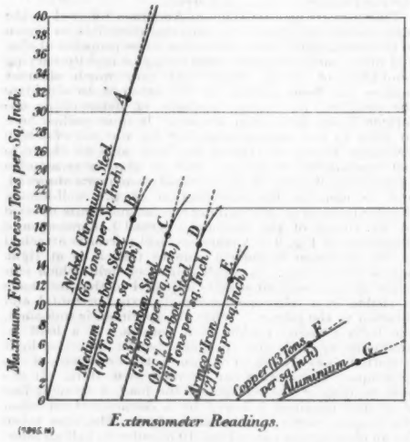


engines of his day—Carnot refers in particular to the high-pressure engines of Trevithick and Vivian (*deux habiles ingenieurs Anglais*)—working at pressures of 8 or 10 atmospheres, but without condensers—to the turbine which now drives our 20,000-ton liners, or through the primitive hot-air engine of Stirling or the early Otto machines, to the Rolls-Royce and the Napier "Lion" of modern aeronautics. But abstract science has marked every step of the journey, and progress has been rendered possible only by the labours of many investigators who have determined such necessary qualities as the heat

Year.	Destination.	Full Load.	R.P.M.	Full Load.*	Steam Pressure, Gauge.	Steam Temperature.	Exhaust Vacuum.	Remarks.
		kw.		Lb. per kw.-hour.	Lb. per sq. in.	deg. F.	in.	
1921	Treforest ..	15,000	1,500	9·10	325	725	29·10	Single cylinder.
1923	Chicago ..	50,000	1,800 H.P. I.P. 720 L.P.	7·40	550	750	29·25	Three cylinders (steam re-heated to 700 deg. F. after high-pressure exhaust).

* Guaranteed figures.

Fig. 10.


Maximum Fibre Stress: Tons per Sq. Inch.
Nickel Chromium Steel (65 Tons per Sq. Inch)
Medium Carbon Steel (40 Tons per sq. Inch)
0·3 Carbon Steel (37 Tons per sq. Inch)
0·15 Carbon Steel (31 Tons per sq. Inch)
"Armco" Iron (21 Tons per sq. Inch)
Copper (13 Tons per sq. Inch)
Aluminium
A
B
C
D
E
F
G

Extensometer Readings.

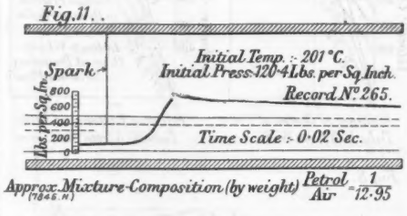
Material.	Curve.	Stress at Limit of Proportionality.	Endurance Tests. Applied Stress.	Endurance Tests. Reversals to Fracture.
Nickel chromium steel	A	± 31·4	± 31·0	10·0*
			± 32·0	0·9
Medium carbon steel	B	± 18·9	± 18·6	10·0*
			± 19·3	1·85
0·3 per cent. carbon steel	C	± 17·4	± 17·0	150·0*
			± 17·7	3·0
0·15 per cent. carbon steel	D	± 16·2	± 15·9	150·0*
			± 16·4	1·65
"Armco" iron ..	E	± 12·5	± 12·2	40·0*
			± 12·8	1·13
Copper	F	± 5·96	± 5·75	13·0*
			± 6·17	6·2
Aluminium ..	G	± 3·0	± 3·74	18·0*
			± 4·1	3·5

* Signifies unbroken.

of combustion of the materials used as the working substances, their specific heats up to temperatures of 2,000 deg. C., and have measured the rate of propagation of flame through the gases produced, its variation with the pressure, and the effect of small changes in the exploding mixtures. Superposed on these have been inquiries into the distribution of temperature in the cylinder, the rate of loss of heat by conduction and radiation, and many metallurgical investigations with a view of finding material suitable to stand the heavy stresses imposed on pistons and other moving parts and yet sufficiently light to satisfy the demands of the designer of the aircraft.

In this work many have combined to help; perhaps I may mention specially, the Light Alloys Sub-Committee of the Aeronautical Research Committee, the work of the Metallurgical Department of the National Physical Laboratory and of Professor Lea of Birmingham, with the Internal-Combustion Engine Committee of the British Association, which numbers among its members men so well known to this Institution as Sir Dugald Clerk, chairman, Professors Callendar, Coker and Dalby, and in days gone by inspired much of the work of Bertram Hopkinson on the explosion of gases. To Callendar we owe the platinum thermometer, which has added so greatly to the accuracy of thermometric work. His work and that of Dalby, with his ingenious device for inserting the thermometer in the cylinder at the right instant, have rendered possible the determination of the temperature at each stage of the engine-cycle, provided we can draw the indicator diagram, and this the researches of Dalby again have made possible. As a result of all this we can obtain in any case the materials for drawing up a heat balance-sheet for the engine, while in quite recent years the work of Ricardo has indicated means for securing a greater efficiency, especially at high altitudes, and much light has been thrown on the problem of detonation by his investigations, combined with those of Fenning at the National Physical Laboratory. Fig. 11 shows one of the explosive curves obtained by him during the explosion of an air petrol mixture in a closed cylindrical vessel, 7 in. in diameter by about 8 in. in length. The mixture prepared in a separate vessel, was ignited in a stagnant state by a high-tension spark situated approximately at the centre of the explosion cylinder,

Fig. 11.



Approx. Mixture-Composition (by weight) Petrol / Air = 1 / 12·95

a secondary spark gap being employed to record the passage of the spark on the diagram.

The record clearly illustrates (1) the delay between the passage of the spark and the apparent commencement of any rise of pressure, (2) the comparatively slow rise of pressure, and (3) a sudden rise just before the maximum, resulting in a metallic ring and corresponding, no doubt, to "pinking" in an actual engine. The latter portion of the cooling curve is a broken line due to the operation of an interceptor actuated by a tuning fork to obtain the time scale, the distance between corresponding points on alternate dashes representing about $\frac{1}{50}$ second.*

And, to return to the steam engine, Sir William Anderson, in his lecture, referred to the rude and cheap apparatus with which Watt in the astonishingly short period of two years, "furnished himself with the abstract knowledge required for explaining in a definite manner the action of the steam engine," and then "had no difficulty, as soon as his theoretical ground was sure, in determining what mechanical arrangements were necessary to realise the conditions imposed by science."

I have neither the time nor the skill to trace in detail the steps by which the genius of Parsons was led to develop the turbine, or to narrate the history of its growth from the Turbinia to the present day.

The main facts are these: In 1897 the Turbinia, of 44½ tons displacement, 100 ft. in length, attained a speed of 34 knots during the Naval Review at Spithead. The shaft horse-power was about 2,100 and the revolutions 2,000.

Ten years later came the Mauretania and Lusitania with four propellers and a shaft horse-power of 70,000; while in H.M.S. Hood (1919) there are four separate sets of turbines, each driving a propeller through gearing, with a total horse-power of 144,000. At that date the total shaft horse-power of geared Parsons turbines was 17,000,000.

The table above gives particulars of two of the latest land turbines constructed by the company.

It is common knowledge, or if not, a glance at any recent article on the subject will confirm it, that practically each step of the progress shown by these facts is based on abstract investigations; the properties of steam as it expands through a nozzle, the efficiency of various forms of nozzle, the effect of superheating, the properties of the material of the blades, questions of balancing the form and construction of the gearing and many other details have formed the subject of experiments, started it is true in many cases, with a view to improving the performance of the turbine, but based in almost all on some fundamental law or principle of abstract science.

As in Watt's steam engine, so in the turbine, we see the work of a man "who is a born mechanic as well as a seeker after physical knowledge"; the combination of the two is required for any real advance in engineering science.

And now to conclude. There is much more that might be said, many more instances in which the discoveries of abstract science have been the foundation of the triumphs of the engineer, but I have trespassed sufficiently on your time. I have given you, I trust, sufficient examples to prove the interdependence of the two. Modern civilisation is based on abstract knowledge, and all experience goes to enforce the dictum of my predecessor thirty years ago, that "the days are past when an engineer can acquit himself respectably by the aid of mother-wit alone, or of those constructive instincts" which in the past led our predecessors to such brilliant results.

* Further particulars are:—

Fuel: Shell aviation spirit.

Initial pressure of charge: 120·4 lb. per square inch (absolute).

Maximum pressure after ignition: 764 lb. per square inch (absolute).

$$\frac{\text{Maximum pressure}}{\text{Initial pressure}} = 6{\cdot}35.$$

Pressure $\frac{1}{10}$ second after maximum: 636 lb. per square inch (absolute).

Initial temperature of charge: 201 deg. C.

Explosion time (*i.e.*, passage of spark to maximum pressure: 0·049 second).

Time interval from apparent commencement of rise to maximum pressure: 0·0404 second.

Ratio of air to petrol by weight = 12·95 to 1.

Partial analysis of cooled products of combustion: CO_2, 12·6 per cent.; O_2, 0 per cent.; CO, 3·65 per cent.

SINGLE METALLIC CRYSTALS.*

The Production of Single Metallic Crystals and some of their Properties.

By Professor H. C. H. CARPENTER, F.R.S. (Royal School of Mines).

(*Concluded from page* 582.)

PRODUCTION OF SINGLE CRYSTALS IN ROUND BARS.

One inch diameter bars of the same purity as the sheet were used. Two sets of test-pieces were machined from them, the diameters being 0·564 in. and 0·798 in., respectively. These were heated at 550 deg. C. for six hours, and given an extension of 2 per cent. on 3 in., and heat treatment as in the previous tests. This treatment was successful. On one occasion, out of 18 test-pieces, eight consisted entirely of a single crystal over the whole parallel portion. It extended up into the shoulders of the test-piece, where an irregular boundary was formed. Three others were monocrystalline, except for one or more small crystals which intruded at the shoulders. Table III gives the mechanical properties of some of the crystals obtained. As in the case of the sheet, the properties vary considerably in different specimens, the tenacities ranging from 3·0 tons to 4·0 tons per square inch, and the elongations from 55 per cent. to 87 per cent. in the case of single crystals. No. 10, which had an elongation of 87 per cent. before fracture was quite completed, is comparable with the value of 86 per cent. obtained with a single crystal in the sheet. The specimens marked with a star were removed from the machine at different stages before fracture was complete, so as to study the method of fracture. The elongations are therefore lower than they would have been if the halves had actually parted.

TABLE III.

No.	Tensile Strength. Tons per Square In.	Percentage Elongation on 3 In.	Number of Crystals in Bar.
1	3·4	76	One crystal.
2	3·0	76	One crystal and small one at shoulder.
3	3·0	78	One crystal which twinned on pulling.
4	3·1	68	One crystal and small crystals at shoulder.
5	4·0	71	One crystal.
6*	3·3	56	One crystal.
7*	3·5	60	One crystal and small one at shoulder.
8	3·9	55	One crystal and two small ones one end.
9*	3·8	65	One crystal and small one at shoulder.
10*	3·06	87	One crystal.
11	3·4	59	Two parallel crystals, fracture across two.
12	3·7	40	Two small parallel crystals at one end; the rest consisted of one crystal in which fracture occurred.
13	3·4	66	Three crystals, fracture in one.
14	3·1	64	Two parallel crystals at one end; the remainder consisted of one crystal in which fracture occurred.
15	3·3	69	Two crystals, fracture across one.
16	3·1	77	Two crystals, fracture across one.
17	3·5	50	One crystal at each end, and one in the middle, across which fracture occurred.
18	3·3	50	Two crystals, fracture across one.
19	4·82	44	Bar consisting of small crystals heated six hours at 550 deg. C.
20	4·88	44	

The table also contains values found in test-pieces consisting of two or three crystals. The last two values are those obtained for bars containing the usual number of small crystals in the annealed condition, *i.e.*, about 150 to the linear inch, or 3,500,000 in a cubic inch.

Except that some of the crystals twinned on pulling, while others did not there were no different types of fracture such as were found in the sheet, but the deformation of the test-piece was very remarkable in all cases and deserves special mention. On the one hand the bar consisting of small crystals drew down in the ordinary way with a roughening of the surface a cup-and-cone fracture and the maintenance of a circular cross-section. On the other hand the single crystals flattened very much in one dimension whereas the other dimension differed but little from the original diameter of the bar. Diagram III. shows (1) a section of the original bar (2) a section after pulling so as to cause considerable distortion, and (3) a section at the fracture. The end result was not a cup-and-cone fracture at all, but what may be described as a double groove. The method of fracture was very

* Paper read at the meeting of the Iron and Steel Institute, Thursday, May 10, 1923.

peculiar, and can best be described with the aid of diagrams. When the bar began to break it drew down sharply in the same direction in which it thinned, and a lens-shaped area was formed (Diagram IV) (1). As the bar pulled apart this became smaller and smaller (2). It parted first at each side, and then in the middle (3). A section cut through the fracture illustrates the thinning at right angles to the plane, depicted in (1), (2) and (3), and shows the curious double-grooved fracture with flow lines, which was always obtained (4). This type of fracture was found in all the bars where fracture actually occurred across single crystals. Photographs of some of these bars are given on Fig. 5, page 581. In the case of each pair one-half of the test-piece is placed so as to show the broad side, while the other half is turned at right angles to show how it thinned.

Considerably more difficulty was experienced in converting the crystals in the 0·798-in. diameter bar into a single crystal. After several attempts, however, bars were obtained in which single crystals extended over the entire cross-section. In one case the whole of the parallel portion of the test-piece was found to consist of one single crystal, while in several others more than three-quarters of the parallel portion was thus occupied. Many of the bars consisted of two crystals, but in the majority of cases these existed side by side and not end to end, so that fracture always occurred across both of them. Most of these bars twinned on pulling, so that the fracture was often uneven and did not show the definite shape obtained in the 0·564-in. diameter bars. In addition to the above, 1-in. square bars were treated. Owing to the shape, however, these failed to strain uniformly, and on heating crystals grew from the four corners and met in a line in the middle of the four sides. Some of the crystals were from 2 in. to 3 in. long, and were visible on two adjacent sides. Remarkable effects were obtained on breaking these. In some places the corners became rounded, while in others they were narrowed to a ridge, almost of knife-edge thickness. The whole bar became very much twisted and distorted. Attempts were made to measure the Brinell hardness number on two adjacent sides of the same crystals. The lowest available load, however, was 500 kilogrammes, and the depression made was so large, owing to the softness of the metal, that it could not be made on one side without affecting the other. It was, however, possible to make depressions in some crystals which were sufficiently near the centre of the bar to obviate all risk of being affected by the edges. These were not round, as is the case with metal consisting of small crystals. Most of them were almost square with rounded corners, but they differed from crystal to crystal according to the orientation. Diagram No. V shows Brinell depressions produced in three crystals.

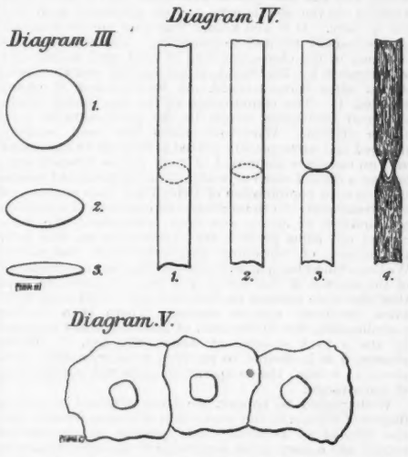
When, as in certain cases, the pieces broken in the tensile tests were heated, recrystallisation was brought about. The temperature at which this began, and the size of the new crystals produced, depended on the amount of deformation of each particular crystal. Those which had been least deformed produced the largest new crystals. It was always found that the new crystals grew from the region of maximum stress, *e.g.*, from the fracture itself, from scratches on the surface and from crystal or twin boundaries. On heating a broken single crystal the smallest of the new crystals are found at the fracture, and the size increases up to the shoulders, where the stress has been least. The new crystals were elongated in the direction of pulling, but frequently sloped sideways, as if following the direction of the slip-bands. Some of the new crystals showed well-marked twins, resembling those in copper and brass, and one example was obtained in which the twinned crystal completely penetrated the sheet.

The foregoing is an account of the tensile tests carried out by Miss Elam and the author on single crystals, both in the sheet and in bars. The numerical values obtained refer only to the end results, and the description of the method of distortion has been purely qualitative. A very interesting and detailed investigation, however, has recently been carried out at Cambridge by Mr. G. I. Taylor and Miss Elam, on the distortion of one of these crystals during a tensile test. The results formed the subject-matter of the Bakerian lecture delivered before the Royal Society on February 22, 1923. The precise object of the test was to determine the nature of the distortion which occurs when a crystal of aluminium is extended by a direct pull, and to find out the relations between the direction of the pull and the orientation of the crystal axes.

A rectangular specimen, 1 cm. by 1 cm. by 20 cm., was cut from a round bar of aluminium which had been treated by our method, so that it consisted of a single crystal. This was stretched through successive extensions of 5, 10, 20, 30, 40, 60, and 78 per cent. of the original length when the crystal broke. At each stage of the test the distortion was determined by measurements of scratches which had been ruled on the surface, and, at the same time, the directions of the crystal axes were determined in each case by X-ray analysis. To quote Mr. Taylor's words: "The method developed for determining the nature of the distortion, by which any configuration of the specimen was strained into any other, was to find lines of particles which were unextended by the strain. The directions of these lines lie on a quadric cone, which evidently has two positions corresponding with the two configurations from which it was derived. On applying this method to the specimen under consideration, it was found that for all stages of the extension up to 40 per cent. elongation, the "unextended cone" was of a degenerate form, consisting of two planes, one of which contained in all cases the same particles, while the other contained different particles for different strains. The former plane was evidently undistorted during the whole strain up to 40 per cent. elongation, and this distortion was due to slipping or shearing over this plane. The orientation of the crystal axes was determined by X-ray measurements, and it was found that the slip plane was identical with an octahedral (111) plane of the crystal. The direction of the shear was also determined, and found to be along one of the three principal lines of atoms in the octahedral plane. When the specimen was extended beyond 40 per cent. elongation, it was found that the distortion was no longer due to slipping on one plane. This was explained by showing that the effect of the shear was to rotate the axis of the specimen relative to the crystal axes in such a way that another (111) plane came into a position where its inclination to the axis was the same as that of the slip plane. Under these circumstances slipping might occur on both planes simultaneously, and it was verified that this was the case."

These conclusions drawn by Mr. Taylor are of the utmost interest, and the author would like to draw particular attention to one of them, viz., that when the second plane comes into position, after the 40 per cent. extension, slipping occurs on both planes uniformly. It would doubtless have been expected by most metallographers that during the 40 per cent. extension, when slipping occurred on one plane, a certain amount of hardening would have taken place on it, and that when the second plane came into play, after the 40 per cent. extension, the slipping would not have been even. Mr. Taylor's conclusions, therefore, are of very great interest in their bearing on the theory of hardening by cold-work. It certainly seems to be established that when the second plane came into the requisite position as a result of shear, slipping took place equally on both planes, whose hardness was therefore the same.

Mr. Taylor and Miss Elam are carrying out investigations of the distortion of other single crystals prepared by our method. It should be added that the X-ray analysis of the distortion of the crystal was rendered possible by a method worked out by Dr. Müller at the



Cavendish Laboratory, to whom we are much indebted, and it is to be hoped he will publish a full account of this before long.

Ever since these single crystals became available, it has been the author's wish that as many of their properties as possible should be determined. Foremost among these come the elastic constants. With regard to these, the co-operation of the author's colleague, Professor Dalby, of the City and Guilds Engineering College, Imperial College of Science and Technology, and of Dr. Stanton at the National Physical Laboratory, has been of great assistance. With their assistance Young's modulus of elasticity, and the limits of proportionality of a number of single crystals under tensile stress, have been determined and compared with those of the aggregates of small crystals (150 to the linear inch) contained in bars as ordinarily prepared. In addition, Dr. Stanton and Mr. Gough have ascertained the fatigue limits of some of our single crystals and compared them with those of aggregates. It is hoped shortly to publish these results, but it may be said they indicate that the single crystals are not isotropic, and that the properties vary according to the orientation of the crystal.

Miss Elam and the author have carried out compression tests on both round and square bars, in order to ascertain whether large crystals can be produced after deformation by compression, followed by heat treatment. The maximum length of test-piece possible for a square bar of 1 in. diameter section was 6 in. for a compression of 1 per cent. measured on 3 in. Greater compression and longer test-pieces resulted in the bending of the bars. In round bars of 1 in. diameter, the maximum length was found to be 5 in. for a compression of 1 per cent. On heating these test-pieces, large crystals were produced in all cases. A cross-section of the round bars showed them to consist of not more than three crystals in most cases. The square bars had a core of small crystals surrounded by four large crystals, which met in the centres of the faces of the square. Some of these crystals were 3 in. or 4 in. long. It is clear from these tests that the capacity of aluminium to form large crystals is not the result of tensile strain *per se*, but is the result of strain generally.

The very high figures of percentage elongation obtained when some of the single crystal test-pieces were broken in tension showed that the metal in this form was extremely ductile, far more so than when the test-piece consisted of the usual number of small crystals (about 3,500,000 per cubic inch). This has been confirmed by experiments on rolling and drawing single crystals. In a given case, a crystal was rolled down from the original thickness (4 in. by 1 in. by 0·125 in.). At a certain stage, when it had elongated considerably, it was cut in half and one of the pieces was rolled down to 0·0094 in., corresponding to a reduction in thickness of 93 per cent. This rolling was done without any annealing. The strip was still quite malleable, and the operation could have been continued further had the rolls permitted it. This malleability is far in excess of that in the sheet consisting of small crystals.

Wire-drawing is an extremely severe form of mechanical work, and experiments with single crystals showed that these could be drawn from a diameter of 0·564 in. to 0·02 in., and still remain very ductile. In order to obtain a sufficient length of bar for this purpose, test-pieces 16 in. long were prepared, with a parallel portion of 6 in. (diameter, 0·564 in.). Five such bars were completely converted into a single crystal over the parallel portion. In a given case, a test-piece was machined 3·5 in. long and 0·4 in. in diameter. This was drawn down cold to a length of about 112 ft. After this process it was still sufficiently ductile to pass the Post Office test for aluminium wire. Further experiments are being carried out to ascertain the extent of the hardening during the wire-drawing of single crystals, and comparing it with that of a bar containing the ordinary number of small crystals. In any case, it seems clear that the single crystals of aluminium posseas remarkably high malleability and ductility in the cold, and that use might well be made of these properties in manufacturing operations.

Something must now be said about the crystallography of aluminium. Crystals are usually classified according to their external geometrical form, to which their properties are found to be closely related. This method cannot be applied to determine the system to which metallic crystals, produced as above, belong, since they do not possess the external forms of crystals, but take their shape from the test-pieces in which they are grown. As stated, the single crystals grow well up into the heads of the test-piece, and the boundary is clearly shown on etching with a suitable reagent (a 10 per cent. aqueous solution of sodium hydrate). Under these circumstances, the whole area of the crystal reflects the light uniformly. We utilised these etching properties in coming to a decision that we were dealing with single crystals. Considering, however, that this was the first time that such relatively enormous crystals had ever been prepared artificially, we felt that it was essential to check our conclusions by an independent authority who used a different criterion. Accordingly, we sent to Professor Sir William Bragg a number of test-pieces, some of them consisting of the micro-crystalline aggregate, while others were composed of what we regarded as single crystals. He kindly submitted these to an X-ray analysis, which enables the space lattice of the crystals to be determined, and with it the crystalline symmetry. His experiments completely confirmed our conclusions, that we were really dealing with single crystals. Moreover, since then, a further confirmation has been obtained by the experiments of Dr. Müller, already referred to. Hull* was the first to investigate the structure of aluminium crystals in a finely crystalline aggregate, and concluded that the pattern thus obtained corresponds to a face-centred cubic lattice, *i.e.*, the grouping of the atoms is such that there is one at each corner of the cube, and one in the centre of each face, making a total of fourteen in all. This corresponds, as Colonel Belaiew† has recently pointed out, to an octahedron situated within a cube. Sir William Bragg and Dr. Müller have confirmed this for our single crystals. They belong, therefore, to the cubic system, and must have properties consistent with those of that group which possesses the highest degree of symmetry both external and internal. Investigations of the crystals in this system indicate that, as regards certain properties, they are isotropic, while as regards others they are anisotropic. In the former category come the properties of conducting light, heat, and electricity, and the coefficient of expansion. In the latter are grouped elasticity, cohesion, and the conduction of sound. In such cases, however, the properties are closely related to the symmetry, since the maximum and minimum values have been found to coincide with axes of symmetry. Accordingly, the variations in the tensile properties of the test-pieces which have been described are due to differences of cohesion in different planes, which do not all contain the same number of atoms. Although the single crystals obtained in the sheet and bars were formed in the same shaped test-pieces in both categories, it was obvious that their original orientation, relative to the axis of the test-piece, varied considerably. Indeed, it may not have been precisely the same in any two of the cases tested. The shape of both sheet and bar alters when stress is applied, since slip and deformation take place only on certain planes, and the changes in shape observed correspond to the attempt of the crystal to accommodate itself to the stress. Such changes were much greater in some tests than others. Jeffries and Archer‡ recently predicted what the shape of a square test-piece should be after being pulled, supposing that it consisted of a single crystal, and that the planes of slip (shear) were at an angle of 45 deg. to the stress. They concluded that a test-piece should reduce in thickness in one dimension only, and that the

* American Institute of Electric Engineers, vol. xxxviii., Part II, October, 1919.

† Page 323, *ante*.

‡ Metallurgical and Chemical Engineering, vol. xxi, No. 24, June 15, 1921.

fracture should be wedge-shaped. Every one of the bars tested by us shows a wedge-shaped fracture. It is quite certain that the original orientations relative to the axis of the test-piece were not all identical. This means, therefore, that, under the stress, some of the bars must have altered their shape considerably in accommodating themselves to it. This was actually observed, because in certain cases they pulled out with a uniform thinning in one plane; while in others a considerable twist took place. The extreme variations in cohesion found in single crystals produced in the sheet were 2·8 tons to 4·1 tons per square inch. In the bar they were 3·0 to 4·0. It is somewhat surprising that the cohesion of the sheet composed of three and a-half million crystals to the cubic inch is not higher than 4·66 tons per square inch, for it has usually been supposed that metals owe much of their cohesion to the fact that they are aggregates of small crystals oriented at haphazard, and consequently that slip can only occur to a very limited extent, viz., along the planes of those particular crystals which happen to be placed in the direction of minimum cohesion relative to the stress, and that the adjacent crystals, more favourably placed for resisting the stress, support them. It will be seen that the highest value of cohesion obtained for a single crystal in the sheet was nearly 90 per cent. of that of the microcrystalline aggregate, while in the case of the bar it was 82 per cent.

Two questions now come up for consideration: (1) Why do abnormally large crystals form on heating after a small deformation, and gradually decrease in size as the deformation increases? and (2) to take the extreme case, why, after a particular degree of deformation, is it possible to form a single crystal from an aggregate of several millions? It will be convenient to consider these questions in the order mentioned.

As mentioned above, the first effect of small amounts of deformation by tensile stress is to produce slip-bands and in some metals twins, but provided the stress does not exceed a certain value, this is all that happens. Very little more deformation, however, causes a change in a few of the crystals, so that on heating they grow. At present it is not known what this change is; but whatever it be, the less the strain the fewer the centres from which growth will start, and hence the larger the crystals ultimately formed. In a given case the largest crystals began to appear after 2 per cent. elongation, followed by heating at 550 deg. C., but their capacity for growth was exhausted when only about one-half of the total number of crystals had been absorbed. At 645 deg., however, they were able to effect complete absorption, owing to the greater mobility conferred by the higher temperature; but in its turn, the higher temperature enabled the growth to start from more centres, so that actually the final crystal size was smaller than at 550 deg. C. As the deformation is increased, more crystals will be strained to the critical amount to produce growth on heating, and there will accordingly be a corresponding decrease in crystal size. This corresponds to the effects observed. In all these cases the microcrystalline aggregate, after the test-piece has been strained, is in the plastic condition. Knowledge of this subject at the present time rests principally upon the well-known researches of Sir George Beilby. According to him, when once the plastic state is reached, vitreous amorphous films are formed along certain planes in the crystals. It might be considered that the crystal growth observed on heating the strained test-pieces was connected with some property of these films. This is why we carried out the experiments summarised above, in which test pieces of aluminium were strained and heated at 350 deg. C. This is sufficient completely to soften the metal, and therefore, by hypothesis, to reconvert the vitreous amorphous films into the crystalline state. At this temperature no crystal growth is observed. If, however, test-pieces were afterwards heated at 550 deg. C., they produced large crystals equal in size to those normally produced at that temperature for the same degree of strain. These experiments show conclusively that a vitreous amorphous phase has nothing whatever to do with the crystal growth observed by us.

For the coalescence of the minute crystals in the test-pieces into large crystals, there is one condition which we regard as essential, viz., that all the crystals must be in a strained condition. Our own experiments have shown that, in the absence of a change of phase, crystal growth will not take place in a metal unless it has been plastically deformed and subsequently heated to a certain temperature for a certain time. As confirming this view, it should be pointed out that there was nearly always a strip of small unaltered crystals on either side of the flat ends of the test-pieces, even when they had been heated at 645 deg. C., and that the large crystals showed no tendency to grow into them. Owing to their position, they had not been strained by the pulling of the test-piece. It seems clear, therefore, that the crystals must be strained to some extent if they are to coalesce after heating.

Coming to the second question, what has to be explained if possible is, why, after a tensile stress producing an elongation of 1·6 per cent. on 3 in., followed by somewhat prolonged heating at 550 deg. C., a single crystal is formed from the large number of small crystals originally present? It is convenient to assume that the orientation of these crystals was quite haphazard before the stress was applied. This explains, as has been mentioned, the fact that such a test-piece is isotropic. The effect of the tensile stress will be to give the crystals a certain small pull in one direction. The conditions for the production of a single crystal from this mixture are considered by Miss Elam and myself to be, that every crystal in the complex must be strained a certain amount, and that one of them is strained rather more than the rest. This particular crystal may be regarded as being in the condition of critical strain, and ultimately all the other crystals align themselves upon it after sufficient heating. When this condition is realised, the test-piece consists of a single crystal. It has been suggested by Mr. U. R. Evans* that the least deformed crystals are the most active in crystal growth, and that the more strained crystals align themselves upon them. If this explanation be correct, then it is the least deformed crystal which ultimately imposes its orientation upon that of the others. At present it cannot be stated which of these views, or indeed if either of them, is correct. This is why we have taken up the experimental investigation of the deformation of the test-pieces by X-ray analyses. We are hoping that the result of this will be to show what it is that happens when a test-piece is strained to the critical amount and is subsequently heated. It is very interesting and significant that this method of investigation, so far as it has gone, tends to show that when metallic crystals are plastically deformed the deformation takes place by means of slip on certain planes in a regular manner, and that the structure of the crystal is maintained. This has been shown by Mr. Taylor, Miss Elam, and Dr. Müller in the experiments already referred to, and in this case the deformation was carried up to 78 per cent. elongation. Burger† has recently studied the structure of drawn tungsten wires by Röntgen ray analysis. He used homogeneous and heterogeneous rays, and obtained concordant results. His conclusion is that the space lattice of tungsten is not altered by drawing, but that in a drawn wire the crystals are directed in such a way that the (110) planes are by preference perpendicular to the axis of the wire, and that after annealing at high temperatures this orientation partly persists. Considering the severity of the mechanical work produced by wire-drawing, this persistence of crystalline orientation is evidence of its great stability.

It can hardly be doubted that the method developed by us of producing very large crystals of aluminium by a combination of mechanical strain and heat treatment is capable of extension to other metals, and, indeed, during the last two years, Miss Elam and I have been working on the metals iron, copper and silver with this end in view. It is well known that iron can be obtained in the coarsely crystalline condition. The large crystals obtained in the close-annealing of mild steel sheets, and investigated by Dr. Stead, are a case in point. These sheets, after being worked, are heat-treated at about 800 deg. C. The combination of the mechanical strain and heat treatment results in the production of very coarse crystals. Wire-rope which has been severely strained and subsequently heated is liable to be converted into an envelope composed of very coarse crystals containing a core of small crystals. Sauveur produced coarse crystals by a combination of Brinell ball impressions and heat treatment. All these are special instances of a suitable combination of strain and heat treatment. We have carried out some preliminary experiments on iron with the object of obtaining monocrystalline test-pieces. We have found here, as with aluminium, that the condition of the surface of the metal is of great importance, and that the scale present on iron and very mild steel militates decidedly against success. There is a further complication, due to the limit of heat treatment imposed by the α to γ change, at about 900 deg. C. Quite clearly, if it is desired to produce monocrystalline test-pieces of α iron, the temperature must not exceed that of the α range.

With regard to copper, we have attained a certain degree of success in the production of coarse crystals, but the streaks of cuprous oxide present in commercial copper are a very great hindrance to the coalescence of the small crystals which have been strained and heated. Accordingly, we have obtained samples of electrolytic copper sheet rolled direct from the cathode metal which are quite free from oxide, and will prove, we hope, suitable for experiments with this metal. Copper, however, shows a complication to which aluminium is much less liable, though it is not entirely free from it, viz., the tendency to form large numbers of twin crystals when the strained metal is heated. This undoubtedly is going to be a difficulty in the production of monocrystalline test-pieces of this metal. Up to the present we have attained more success with silver than with either iron or copper. We have been able to produce crystals of this metal up to ½-in. diam and ¼-in thickness. Silver can be obtained in a state of high purity and contains no film of oxide, but it shares with copper the tendency to form twin crystals when strained and subsequently heated. I hope before long that Miss Elam and I will be in a position to publish definite experimental results with these metals.

The photographs are reproduced with the kind permission of the Royal Society.

* Journal of the Institute of Metals, No. 1, 1921, vol. xxv., p. 299.

† Nederlandsch tijdschrift voor Natuurkunde, Jaargang, 1921, 214–218.

‡ Paper read at the meeting of the Iron and Steel Institute, on Thursday, May 10.

BLAST FURNACE COKE.

The Reactivity of Coke as a Factor in the Fuel Economy of the Blast Furnace.‡

By E. R. SUTCLIFFE and EDGAR C. EVANS.
With a Note by R. V. WHEELER.

(*Continued from page* 605.)

Effect of Solution on Fuel Consumption.—Gruner's theorem and Johnson's calculations emphasise the fact that the ideal to be aimed at is a zero solution loss; the 100 per cent. of the carbon charged should therefore be burned at the tuyeres by the blast. It is generally admitted that, as a rule, Gruner's ideal corresponds with maximum fuel economy, but Richards* states: "If the blast be heated to a very high temperature, or particularly if it be dried, or if the ore and fuel are extra pure, so that a smaller quantity of heat is needed to melt down the slag at the tuyeres, there may not be needed at the tuyeres the generation by combustion of as much heat as Gruner's ideal working would require, and cause to be produced, and to burn all the carbon oxidised in the furnace would be wasteful of fuel. In this case, although less heat would be generated per unit of fuel by burning some of it above the tuyeres, yet economy in fuel consumption as a whole would be attained because of the better distribution of the heat which was generated from a smaller total quantity of fuel." "The ordinary furnace produces at the tuyeres more CO gas than is needed to abstract all the oxygen from the charge; under these conditions it is uneconomical to oxidise any carbon at all above the tuyeres. The exceptional furnace, because of pure ores, small amount of slag, pure fuel, high temperature of blast, or dry-blast, gets heat enough at the tuyeres to melt down the charges without producing enough CO gas to reduce all the charges; under these conditions more or less reduction is effected in quantity by solid carbon and with the greatest economy in quantity of carbon required in the furnace. These are the conditions under which, having passed the turning point, the greater economy of fuel is attained the farther away one can get from Gruner's ideal working."

Richards' theoretical conclusions are emphasised by the results quoted by Howland† and reproduced in Tables I, II, and III.

It is important to note that the furnaces referred to in the tables were all working with the same ores (Mesaba), and were all modern furnaces, representative of good American practice.

From the tables it can be seen that:—

1. The blast per pound of coke varied from 48·0 cubic ft. to 54 cubic ft. of air.

2. The proportion gasified at the tuyeres varied from 74·1 to 82·8 per cent. of the coke used.

3. There is no law governing the coke consumption and the percentage of carbon burnt at the tuyeres.

4. The lowest fuel consumption on the above list was accompanied by a solution loss of 25·2 per cent. of the total carbon charged.

On the basis of the results obtained Howland proceeded to calculate the thermal efficiencies of one of the furnaces on the following assumptions:—

A. That a proportion of the carbon was used in the direct reduction of the ore, the remaining ore being reduced by carbon monoxide, all excess carbon monoxide passing to the top gases.

B. That all the carbon monoxide made at the tuyeres reduced the ore, and that the excess carbon was used up by carbon dioxide.

C. That the total consumption of carbon was the same, but that it had been all burnt at the tuyeres.

Cases A and B correspond with solution loss either by direct reduction or by solution in the carbon dioxide, whilst the third assumption corresponded to Gruner's ideal.

The results of these calculations are shown in Table III.

It is evident that if Gruner's ideal had been adhered to the net result would have been a considerable reduction in efficiency.

In conclusion, Howland states: ". . . Low coke consumption goes hand in hand with low wind. . . . The lower volume of gas means, in a hearth of a given area, a lower velocity of the gases, thus tending to concentration of heat." Low wind is, of course, indicative of high solution loss, and apparently then high solution loss is accompanied in favourable cases by low fuel consumption.

The above particulars, together with results obtained with charcoal furnaces, all point in the same direction, namely, that far from being a deleterious property, a high solubility factor in a coke is a most important asset in securing a low fuel consumption. This conclusion receives considerable emphasis if the question be examined from a slightly different standpoint.

Combustibility—The most important Property in a Coke.—The solubility of a coke is in itself a measure of its combustibility. The most accurate and probably the simplest method of determining the reactivity of a coke is to make actual measurements of the rate at which it combines with oxygen under standard conditions at a given temperature, say 400 deg. C.; and the rate at which carbon dioxide is reduced by it at a given temperature, say 900 deg. C. A note on this subject, with a record of some of the results obtained with different fuels, is given as an addendum to this paper by Professor R. V. Wheeler.

The conception of combustibility as a factor in blast-furnace practice is not altogether new. It does not play a very important part in Bell's writings. He devotes a great deal of time to the question of solution, but the nearest approach by him to the idea of combustibility of a fuel influencing blast-furnace results is perhaps contained in the conclusion that he was forced to arrive at in his endeavours to explain the reasons for the high thermal efficiencies of charcoal furnaces as compared with coke furnaces. This is, that "the circumstances attending the combustion of charcoal differ from those of coke."‡

Contemporaries and predecessors of Bell, however, devoted a fair amount of attention to this question, and this was especially true in cases where they had personal experience of charcoal furnaces. A study of some of

* "Metallurgical Calculations," p. 275.

† Transactions of the American Institute of Mining Engineers, 1917, vol. lvi., p. 339.

‡ Bell, *op. cit.*, page 282.

the older literature of this period when charcoal was still extensively used as a furnace fuel makes very interesting reading. Percy,* for example, quotes a number of experiments that had been performed chiefly by Violette with reference to the combustibility of charcoal prepared at various temperatures; the lower the temperature of carbonisation, the higher the combustibility. Further,† he quotes the economies obtained in melting iron with imperfectly burnt charcoal ("charbon roux"). Work on this particular question had been performed as far back as 1835, and some of the earlier American writers also laid emphasis on this fact.‡ It was the general opinion in American charcoal practice of that period (1875–80) that the use of imperfectly burnt charcoal was always attended by the maximum of fuel economy.

Further, it was well known that charcoal gave much better results in the blast furnace than either coke or anthracite. In the paper already referred to, Church§ went in detail into the cause of the superiority of charcoal. He gave two view-points as to the reason for this: (1) the scientific view-point represented by the theories of Akerman, and (2) the practical view-point. Akerman and his school had contended that charcoal—owing to its high porosity—reduced the carbon dioxide more rapidly than either coke or anthracite. At that time it was considered that carbon dioxide was the first product of combustion, this being subsequently reduced to carbon monoxide, a theory exploded by the work of Wheeler and his collaborators. Practical men, on the other hand, considered that the low consumption of charcoal in the furnace was due to its higher rate of combustion, resulting in a higher temperature in the hearth. Church considered both explanations—the practical and scientific—to be fallacious. A correct theory would have to be in agreement with the practical observations that (*a*) for a given weight of fuel, the well of a charcoal furnace was hotter than that of a coke furnace, and (*b*) that more fuel reached the hearth of an anthracite furnace than that of a coke furnace.

The highest carbon duty was given by a fuel which withdrew most of the oxygen from the blast in a given space of time, or, in other words, the duty was proportional to capacity for combustion in extremely dilute oxygen. As long as the oxygen percentage in the blast remained within certain limits fuel of any kind would take it up easily, but when that oxygen was reduced to about 10 per cent. (the limit when flame was extinguished is oxygen 10 per cent., carbon dioxide 8 per cent. to 10 per cent.), the fuel which combined with it more rapidly was the superior. With a fuel of low combustibility, free oxygen was carried to the boshes to be consumed away from the zone of highest temperature, thus necessitating an increased fuel consumption to maintain the necessary heat at the hearth.

The question was later followed up by Thorner,* who made a detailed investigation on a number of blast-furnace fuels consisting of several varieties of coke, charcoal and anthracite, and determined their actual specific gravities, porosity, strength under compression, rate of solubility in carbon dioxide, and combustibility in air. He also made microscopic examination of sections of these fuels with a view to determining the influences of their structure upon the above properties. His results can be summarised in Table IV. Taking a general view of Thorner's work in so far as it concerns the blast furnace, his opinion can be summarised as follows:—

1. The best results in blast-furnace practice were obtained with Meiler coke and with charcoal—both fuels possessing the following characteristics: (*a*) High proportion of volatile matter; (*b*) high degree of

* "Fuel," page 359.

† *Ibid.*, page 409.

‡ Church, Transactions of the American Institute of Mining Engineers, 1875, vol. iv, page 119; Fernow, vol. vi, page 199; and Kent, vol. vi, page 206.

§ Transactions of the American Institute of Mining Engineers, 1878, vol. vii, page 33.

* "Contribution to the Study of Coal, Coke and Charcoal as Fuels for Blast Furnaces," *Stahl und Eisen*, 1886, vol. vi, page 71.

TABLE I.—HOWLAND.

Furnace No.	Month and Year.	Lb. Coke Per Ton of Iron.	Tons Iron per Day.	Carbon in Coke. Per Cent.	Kind of Coke. Method of Manufacture.	Kind of Coke. Operation.	Gas Analysis. Per Cent. by Volume. CO_2.	CO.	CH_4.	CO_2 plus CO plus CH_4.	N.	H.	Calculated Quantities. Per Ton of Iron. Lb. Carbon to Gas.	Cub. Ft. Gas. 62 Deg. F.	Cub. Ft. Air, 62 Deg. F.	Cub. Ft. Air per Lb. Coke.	Pounds Carbon. Per Ton of Iron. Total Charged.	Gasified in Furnace.	Gasified at Tuyeres.	Per Cent. Carbon Burned at Tuyeres. Per Cent. Total Carbon.	Per Cent. Gasified Carbon.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
1	12/11	2,615	301	86·3	BH	Stonega	10·3	27·6	0·2	38·1	59·8	2·1	2,251	187,200	141,600	54·2	2,254	2,110	1,868	82·8	88·6
2	1/12	2,551	272	84·4	BP	Solvay	11·3	26·9	0·6	38·8	59·0	2·2	2,182	178,200	132,800	52·0	2,153	2,049	1,179	81·4	85·6
3	1/13	2,472	472	86·1	BH	Conn.	12·3	25·8	0·0	38·1	58·4	3·5	2,133	177,300	131,000	53·0	2,128	1,996	1,728	81·2	86·6
4	12/14	2,247	450	87·1	BH	Conn.	11·8	26·2	0·1	38·1	58·5	3·4	1,978	164,440	121,600	54·2	1,957	1,846	1,605	82·0	87·0
5	8/14	2,198	499	86·9	BH	Conn.	12·5	26·8	0·3	39·6	58·0	2·4	1,933	154,600	113,200	51·6	1,908	1,813	1,494	78·7	82·4
6	4/14	2,123	541	88·3	BH	Conn.	12·8	26·0	0·2	39·0	58·0	3·0	1,905	154,800	113,500	53·4	1,875	1,764	1,498	79·8	84·9
7	11/13	2,115	360	84·3	BP	Solvay	14·2	25·3	0·0	39·5	57·9	2·6	1,826	146,500	108,200	51·2	1,782	1,683	1,427	80·1	84·8
8	12/14	1,996	490	86·3	BP	Koppers	13·8	26·0	0·2	40·0	57·4	2·6	1,718	136,100	98,800	49·5	1,722	1,616	1,303	75·6	80·6
9	6/15	1,936	376	85·7	BP	Solvay	14·6	24·7	—	39·3	57·4	3·3	1,689	137,000	98,900	51·1	1,659	1,557	1,305	78·9	83·7
10	9/15	1,905	393	88·7	BP	Solvay	14·5	26·0	—	40·5	56·4	3·1	1,700	132,900	94,900	49·8	1,690	1,575	1,252	74·1	79·5
11	2/15	1,901	517	85·5	BP	Koppers	13·6	24·9	0·2	38·5	58·0	3·2	1,600	131,700	96,600	51·8	1,625	1,514	1,274	78·4	84·1
12	11/14	1,863	504	86·6	BP	Koppers	14·0	25·3	0·2	39·5	57·4	2·6	1,602	128,500	90,500	50·0	1,614	1,513	1,230	76·2	81·3
13	5/14	1,780	426	84·9	BP	Koppers	14·2	26·0	—	40·2	56·2	3·6	1,519	120,000	85,200	48·0	1,511	1,414	1,124	74·4	79·5
14	10/15	1,742	503	84·6	BP	Koppers	15·4	22·8	1·2	39·4	57·1	3·7	1,480	119,000	85,925	49·3	1,474	1,382	1,133	76·9	82·0
15	10/14	1,716	542	87·1	BH	Benham	15·7	22·8	—	38·5	57·8	3·7	1,505	123,800	93,200	54·2	1,494	1,396	1,194	80·0	87·0
16	10/15	1,715	585	84·6	BP	Koppers	15·4	22·6	1·4	39·4	57·1	3·5	1,456	117,300	84,530	49·3	1,451	1,357	1,114	76·7	82·2
17	4/14	1,702	543	87·5	BP	Koppers	14·2	25·2	0·2	39·6	57·3	3·1	1,476	127,500	85,600	50·3	1,490	1,388	1,130	75·9	81·5
18	6/14	1,699	572	87·0	BP	Koppers	14·9	23·5	0·2	38·6	57·3	4·1	1,472	120,800	87,600	51·6	1,479	1,376	1,155	78·2	83·9
19	2/15	1,673	580	88·6	BH	Benham	15·1	23·6	—	38·7	58·6	2·8	1,477	121,000	89,600	53·4	1,482	1,384	1,182	79·9	85·0
20	1/15	1,658	590	88·3	BH	Benham	15·5	22·9	0·1	38·5	58·7	2·8	1,467	120,600	89,600	54·0	1,464	1,366	1,182	80·8	86·5
21	5/15	1,636	442	89·5	BP	Koppers	14·2	25·2	0·2	39·6	57·6	2·8	1,464	117,100	85,200	52·0	1,463	1,369	1,124	76·8	82·1
22	5/15	1,635	593	88·5	BH	Benham	15·5	23·3	0·0	38·8	58·3	2·9	1,434	117,000	85,200	52·1	1,447	1,349	1,124	77·7	83·4
23	3/15	1,624	592	87·3	BH	Benham	14·8	23·6	0·2	38·6	58·3	3·1	1,401	115,000	84,800	52·2	1,417	1,317	1,118	79·0	85·0
24	6/15	1,623	457	89·6	BP	Koppers	15·3	24·8	0·2	40·3	57·0	2·7	1,453	114,700	82,600	50·9	1,454	1,360	1,090	75·0	80·2
25	4/15	1,589	608	88·3	BH	Benham	15·3	23·5	0·0	38·8	58·2	3·0	1,390	103,400	83,300	52·4	1,403	1,307	1,100	78·5	84·2
26	7/15	1,584	466	89·2	BP	Koppers	15·7	24·6	0·2	40·5	56·9	2·6	1,423	111,300	80,100	50·6	1,413	1,324	1,057	74·8	79·9

TABLE II.—HOWLAND.

Furnace No.	Dimensions. Heights. Total.	Heights. Tuyeres to Top Bosh.	Diameter. Hearth.	Diameter. Bosh.	Diameter. Stock Line.	Capacity Cub. Ft. Tuyeres to Stock Line.	No. Tuyeres.	Date last Blown in.	Per Cent. Silicon in Iron.	Per Cent. Carbon. Iron.	Stone.	Flue Dust.	Coke Dried.	Screenings.	Per Cent. Moisture in Coke.	Pounds per Ton Iron. Stone Used.	Flue Dust Made.	Engine-Room Reports. Cub. Ft. Air per Min.	Temp. Air to Tubs. Degs.	Grains Moisture.	Per Cent. Coke Screened out.
	ft.	ft. in.	ft. in.	ft. in.	ft. in.																
1	84	13 4½	13 0	19 3	14 0	14,060	8	9–09	1·62	4·0	11·8	25·0	88·7	80·0	2·23	1,192	225	30,040	34	1·83	0·5
2	80	11 0	11 0	16 0	12 0	9,200	8	9–09	1·59	4·0	11·6	5·4	88·5	80·0	4·0	1,148	275	25,295	—	—	0·75
3	89	13 10	15 6	20 6	16 0	18,500	12	9–10	2·13	4·0	12·0	11·7	88·1	—	2·25	1,144	370	45,560	62	1·55	—
4	85	13 0	16 0	22 0	16 0	19,500	12	—	1·56	4·0	12·0	8·2	89·8	82·0	2·5	1.097	461	44,213	82	—	0·56
5	85	13 0	16 0	22 0	16 0	19,500	12	—	1·40	4·0	12·0	8·2	89·4	82·0	2·5	1,003	388	45,839	92	6·44	0·39
6	89	13 10	15 6	20 6	16 0	18,500	12	9–10	1·93	4·0	11·7	12·0	90·7	80·0	2·25	1,208	180	46,090	52	3·15	0·5
7	80	12 11	12 0	18 6	13 6	12,375	8	9–12	1·53	4·0	12·05	11·6	89·1	81·5	4·00	1,190	116	32,390	70	4·28	1·5
8	94	11 7	17 0	21 3	16 3	20,666	12	2–14	1·03	4·2	11·75	9·0	88·5	—	2·50	870	140	39,210	38	1·05	—
9	80	11 11	13 6	18 6	14 0	12,459	8	5–15	0·94	4·1	12·05	4·8	89·4	84·0	3·85	1,101	224	30,799	90	5·9	0·3
10	80	11 11	13 6	18 6	14 0	12,459	8	5–15	1·26	4·4	12·0	8·5	91·6	84·0	2·9	1,042	192	31,120	85	6·6	0·3
11			Same as No. 8						0·90	4·25	11·93	11·45	88·3	—	3·07	719	140	36,824	37	2·58	—
12			Same as No. 8						0·95	4·20	11·75	7·55	88·85	—	2·50	755	98	38,220	54	2·04	—
13	78	19 10	14 0	19 6	15 0	15,584	9	3–14	1·26	4·00	11·70	—	88·00	—	3·50	897	60	29,670	62	—	—
14	85	14 3	15 0	20 6	15 5	nil	12	1–15	1·00	4·00	12·00	2·00	89·1	87·0	4·32	828	135	36,368	60	4·0	1·7
15	90	14 0	16 6	21 6	16 0	20,222	12	9–14	1·62	4·00	12·00	10·0	92·0	80·0	1·55	912	89	35,385	65	—	3·2
16	90	14 3	16 6	21 4	16 6	nil	12	9–13	0·89	4·00	12·00	2·1	89·1	87·0	4·32	833	200	42,765	60	3·9	1·6
17	90	14 6	17 8	22 0	17 0	10,630	10	2–14	1·23	4·20	11·75	6·2	89·5	—	2·25	752	95	42,950	49	2·5	—
18			Same as No. 17						1·35	4·20	11·75	8·25	89·0	—	2·30	804	82	48,978	75	5·5	—
19			Same as No. 15						1·56	4·00	12·00	9·5	93·3	80·0	1·85	780	94	35,615	62	2·2	3·8
20			Same as No. 15						1·41	4·00	11·9	9·1	92·6	80·0	2·23	849	90	35,820	62	1·7	2·8
21			Same as No. 13						1·36	4·1	12·0	4·8	91·8	—	2·5	792	31	30,050	70	3·8	—
22			Same as No. 15						1·62	4·0	11·9	8·0	92·2	80·0	1·4	709	99	35,210	56	3·8	3·0
23			Same as No. 15						1·48	4·0	11·7	8·8	91·2	80·0	1·6	714	125	35,680	62	1·8	3·0
24			Same as No. 13						1·19	4·1	12·0	6·9	91·9	—	2·5	775	—	29,910	75	5·0	—
25			Same as No. 15						1·67	4·0	11·7	7·1	92·3	80·0	1·5	712	94	35,570	62	3·4	3·3
26			Same as No. 13						1·20	4·1	12·0	7·6	91·5	—	2·5	828	—	30,210	80	6·4	—

solubility in CO_2; (c) high degree of combustibility in air.

2. The inferior results obtained with coke in the blast furnace could be improved by modifying the coke so as to convert the basic substances into an easily oxidisable modification.

3. The ideal blast-furnace fuel should be as similar to charcoal as possible.

Owing probably to the influence of Bell, and the indifference displayed by him to the importance of combustibility, very little work appears to have been done on the subject subsequent to the above until within comparatively recent years. In 1914 a paper was read by Brassert, "On Coke, with Particular Reference to Combustibility." This is reproduced in full by Johnson,*

TABLE III.—*Use of Carbon under Various Assumptions. (Howland.)*

Per ton iron = 2,240 lb.

	Wisconsin Furnace No. 1.		
	"A."	"B."	"C."
1. Coke, pounds	1,673	1,673	1,673
2. Carbon charged, pounds	1,482	1,482	1,482
3. Carbon gasified, pounds	1,384	1,384	1,384
4. Carbon reduction Mn, P, Si, pounds	36	36	36
5. Carbon direct reduction Fe_2O_3, pounds	166	41	0
6. Carbon indirect reduction Fe_2O_3, pounds	807	1,182	1,304
7. Carbon in CO not needed for reduction, pounds	375	0	44
8. Carbon dissolved by CO_2, pounds	0	125	0
9. Carbon gasified at tuyeres, pounds	1,182	1,182	1,348
10. Carbon used in reducing Fe_2O_3, pounds	973	1,223	1,304
11. Cubic feet air per pound coke, 62 deg. F.	53·4	53·4	61·08
12. Analysis of top gas	—	—	—
13. CO per cent. by volume, per cent.	23·6	23·6	17·7
14. CO_2 per cent. by volume, per cent.	15·1	15·1	18·0
15. H per cent. by volume, per cent.	2·7	2·7	2·7
16. N per cent. by volume, per cent.	58·6	58·6	61·6
17. Total B.Th.U. per cubic foot top gas at 62 deg.	84·0	84·0	64·8
18. Cubic feet gas per ton iron	121,000	121,000	131,200
19. B.Th.U. per pound C gasified	7,344	7,344	6,143
20. B.Th.U. in CO per cubic foot top gas	76·6	76·6	57·4
21. B.Th.U. in CO per pound carbon gasified	6,697	6,697	5,441
22. B.Th.U. lost to top gas per pound carbon gasified	—	—	1,256

TABLE IV.—THORNER.

Class of Coal.	Ash.	Specific Gravity.		Porosity 100 Grammes Fuel Content.		Organic Volatile Matter.	Loss in CO_2 in Half Hour.	Loss in Blast in 10 Minutes.
		Apparent.	Actual.	Vol. of Pores.	Vol. of Substance.			
				CO.	CO.	per cent.	per cent.	per cent.
1. Retort coke	3·8	0·858	1·825	61·6	54·8	—	10·6	46·8
2. Gas coke	7·5	0·868	1·811	60·0	55·2	0·25	11·8	45·0
3. Pressed coke	7·7	0·984	1·852	47·6	54·0	1·4	—	51·0
4. Pressed coke	6·9	0·969	1·786	47·2	56·0	1·15	13·8	48·9
5. Coppee coke	7·99	0·926	1·880	54·8	53·2	1·13	8·4	50·1
6. Coppee coke	7·8	0·909	1·825	55·8	54·8	1·55	8·7	54·4
7. Coppee coke	7·3	0·890	1·852	58·4	54·0	1·70	8·3	51·5
8. Coppee coke	10·6	0·919	1·852	54·8	54·0	1·70	8·0	52·9
9. Coppee coke	8·8	0·874	1·852	60·4	54·0	—	9·5	46·8
10. Coppee coke	8·45	0·89	1·894	59·6	52·8	0·75	12·2	57·1
11. Coppee coke	7·6	0·903	1·909	58·4	52·4	—	6·8	52·1
12. Coppee coke	7·6	0·989	1·887	49·0	53·0	—	8·9	52·5
13. Meller	2·9 †	1·046	1·488	28·4	67·2	29·7	45·6	87·7
14. Pine charcoal	2·8	0·382	1·626	200·4	61·6	29·7	—	100·0
15. Oak charcoal	2·45	0·597	1·347	96·2	74·2	17·9	85·0	78·6
16. Beech charcoal	2·10	0·594	1·481	100·8	67·6	13·2	—	80·3
17. Beech charcoal	1·65	0·484	1·351	132·5	74·0	11·8	95·0	100·0
18. Anthracite	9·3	1·572	1·666	3·6	60·0	13·2	95·0	45·4

Microscopic Examination.

1. Large pores, thick pore walls.
2 and 4. Many very small pores.
5, 6, 7, 8. Less small and big pores.
9. Numerous small and many big pores.
10. Small and large pores.
11 and 12. Very large pores.
13. Numerous small pores with pronounced tendency in longitudinal direction.
14. Numerous microscopic small regularly arranged cells of tabular form.
15. Fewer and larger pores.
16. Like pine charcoal but larger cells.

who points out that the value of the coke in relation to the heat reactions in the furnace is determined not only by its carbon content, but even more so by its combustibility. He still, however, considered that high solubility in CO_2 was deleterious, and his ideal coke was one which would burn rapidly at the tuyeres and yet not be too vulnerable to the ascending gases. The combustibility of a coke was influenced by (1) its size, (2) the physical and chemical conditions of the cell wall substance, (3) the interior and surface cell structure of the coke pieces, (4) the character of the coal used, (5) the method of carbonisation adopted, (6) the speed of carbonisation, (7) the method of quenching, and (8) the method of screening and handling. This very brief summary gives an excellent idea of the factors involved in attaining a high degree of combustibility when ordinary methods of coking are adopted.

Howland, in the paper already referred to, emphasises the importance of the factor of combustibility in a coke, and stated that "the most desirable thing about a coke is that quality in the carbon which will allow of it being instantaneously burned to CO, and thus result in the maximum concentration of heat where needed." Later, Koppers,* in a paper read to the Blast-Furnace Committee of the German Iron and Steel Makers, developed the idea of combustibility to a considerably greater extent than had been done hitherto. One of the most important effects produced, in his opinion, was the reduction in the extent of the oxidising zone near the tuyeres.

Professor Wüst had shown some years before that a strongly oxidising zone existed near the tuyeres. Under the influence of free oxygen and of carbon dioxide—which at high temperatures is a powerful oxidising agent—a proportion of the iron became oxidised. This necessitates a further supply of carbon for its direct reduction, resulting in the following series of cumulative effects:—

(1) Higher coke consumption; (2) greater blast; (3) greater heat for blast; (4) greater load on engines; (5) lower production of iron.

A combustible coke offered the following advantages: (1) Reduction in area of oxidising zone at tuyeres. (2) Better iron. He pointed out that in charcoal iron, carbon segregates out in minute leaves of graphite, whilst with coke the graphite in the pig separates as large leaves. The more combustible the coke the more nearly does the iron approach the quality of charcoal iron. There is also less ferrous oxide in the pig. (3) Desulphurisation in the iron is effected better by combustible coke owing to the reduced oxidising zone, less FeO goes into the slag, which is therefore better able to absorb sulphur.

He suggested that modifications in the existing methods of coke manufacture should be adopted in order to increase the combustibility of the fuel for blast-furnace purposes.

The authors have worked upon this question from a rather novel standpoint, but before proceeding to discuss their views it might be of some interest briefly to outline the factors involved in the rapid combustion of coke in a blast furnace.

Factors Influencing Rapid Combustion of Fuel in a Blast Furnace.—This question was recently dealt with from a mathematical standpoint by Korevaar.† Essentially the rapidity of combustion in a blast furnace was dependent on the following factors:—

1. Blast-furnace factors. Dimensions of the furnace—shape—character of material of which it is built, &c.
2. Factors depending on the fuel:—
(1) Activity (or combustibility).
(2) Porosity.
(3) Size of the fuel particles.
3. Factors depending on the blast:—
(1) Velocity.
(2) Temperature.
(3) Concentration of oxygen.
(4) Proportion of water vapour.

Factors Depending on the Fuel. Activity of the Fuel.—1. With a very active fuel, or when the temperature is very high, combustion takes place in a zone of very small volume.

2. With a less active fuel or with lower temperature, the combustion zone is greater in volume.

3. With a poorly active fuel or low temperature, the combustion zone is still larger, and some of the oxygen may leave the combustion zone unattacked.

The value of the zone of combustion can be represented mathematically by the following equation:—

$$O = \frac{2\,O_k\,r_k}{2{\cdot}2215\,r\,.\,P} = \text{volume of zone combustion.}$$

Where O = volume of combustion zone.
r_k = average radius of carbon particles (assumed to be spherical).
O_k = total surface of zone.
P = factor depending on porosity of coke.
r = radius of combustion zone.

This equation gives the relationship between the volume of the zone of combustion and the different factors depending on the fuel ($O_k\,r_k \times P$). The factor r, depending on the furnace, remains constant.

With an active carbon the surface of combustion O_k remains small, so that this factor can serve as a factor of activity. With small particles of carbon r_k becomes small, therefore O diminishes, and with high porosity factor the same thing applies.

Relation between Volume and Temperature of Combustion Zone.—Korevaar calculates that in a gas-producer working under stable conditions with pure carbon:—

$$O = \frac{(417\cdot0{\cdot}24\,t - 0{\cdot}228\,T)}{K\,(T - T_0)} \times \text{kilogram of carbon burnt per minute.}$$

Where t = temperature of blast.
T = temperature of combustion zone.
K = a constant depending on furnace.
T_0 = external temperature.

From this it will be seen that the volume of the combustion zone decreases as the temperature increases, and *vice versa*. If O, the volume of the combustion zone, becomes infinitely small (zero), T would become 1875 deg.—the maximum temperature obtainable with cold air. As, however, O cannot become infinitely small, the maximum temperature will be somewhat lower than this.

In blast-furnace practice Korevaar's mathematical demonstration shows that:—

1. The temperature of the combustion zone can be increased by the employment of a more active fuel.

2. With a more active fuel the necessary temperature can be obtained with a lower fuel consumption.

3. Assuming the temperature of the combustion zone to be constant, the employment of a more active fuel diminishes the volume of the zone of combustion.

4. An increase in blast temperature allows the critical temperature to be obtained with a low fuel consumption.

5. The lowest fuel consumption is obtained by the lowest possible air velocity at the tuyeres, taking into consideration the activity of the fuel and the temperature of the blast. (Compare Howland, "Low coke consumption goes hand in hand with low wind.")

This exposition develops mathematically the contention elaborated in a qualitative manner by Koppers with reference to the influence exerted by the fuel activity on the volume of the oxidising zone, and also explains to some extent the views of Howland.

There is one other theoretical question that needs to be touched upon. Oxidation of the iron in the vicinity of the tuyeres can be effected either by free oxygen or by carbon dioxide.

Influence of Fuel Activity on the Proportion of CO_2 Produced at the Tuyeres.—The researches of Rhead and Wheeler* on the combustion of carbon have shown that—

(1) When carbon burns, both carbon dioxide and carbon monoxide are produced simultaneously.

(2) When carbon burns, it first forms a complex with oxygen, which is afterwards decomposed to a mixture of carbon monoxide and carbon dioxide.

(3) The fixation of oxygen is affected considerably by the "activity" of the carbon (graphite is not affected to the extent that charcoal is), and great care had to be taken in the experiments to obtain a "normal" condition of activity at the outset.

(4) The ratio CO : CO_2 in the products of combustion increased from 400 deg. to 600 deg.; diminished from 600 deg. to 850 deg., and then rapidly increased.

(5) Above 750 deg. the rate of reaction $CO_2 + C = 2CO$ becomes appreciable, the quantity of carbon dioxide reduced depending largely on the length of time it is allowed to remain in contact with the carbon.

(6) Reduction of carbon dioxide becomes very rapid above 1,000 deg. C. (a study of the curves obtained by these writers indicates that at the high temperature existing in the blast furnace the production of carbon dioxide would be extremely small).

In all probability carbon dioxide would only be present in the hearth in the zone where free oxygen also exists, so that any method of reducing this zone would at the same time reduce the possibility of contact of the iron with the oxidising carbon dioxide. In any event the higher the temperature in the hearth, the smaller the possibility of carbon dioxide being present. As an active fuel results in an increased temperature and a smaller zone of combustion, the zone in which carbon dioxide is likely to be present is diminished, and thus the liability of the iron sponge to reoxidation is reduced.

(To be continued.)

THE ABBREVIATION H.P. IN FRANCE.—In the course of a recent meeting of the Association of Gas and Internal-combustion Engine Builders and of Builders of Gas Producers, attention was called, says *Le Génie Civil*, to the error committed in France by the use of the abbreviation H.P., which was a British expression corresponding to the British unit of power, or 76 kilogrammetres, whereas the French horse-power was of only 75 kilogrammetres. The association advocated the use, in its stead, of the abbreviation C.V., corresponding to *cheval-vapeur*.

* J. E. Johnson, *op. cit.*, p. 171.

* *Stahl und Eisen*, August 25, 1921, vol. xli.
† *Chimie et Industrie*, vol. viii, No. 1, July, 1922.

* Transactions of the Chemical Society, 1912, pp. 101, 831; 1912, pp. 101, 846; 1913, pp. 103, 461.